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(54) **PROJECTILE-PROPELLING EXPLOSIVE STRUCTURE**

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F41F 1/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F41F 1/00*** (2013.01)

(58) **Field of Classification Search**
CPC . F42B 3/093; F42D 1/04; F42D 1/043; C06C 5/04; C06C 5/06
USPC 102/275.1, 275.8
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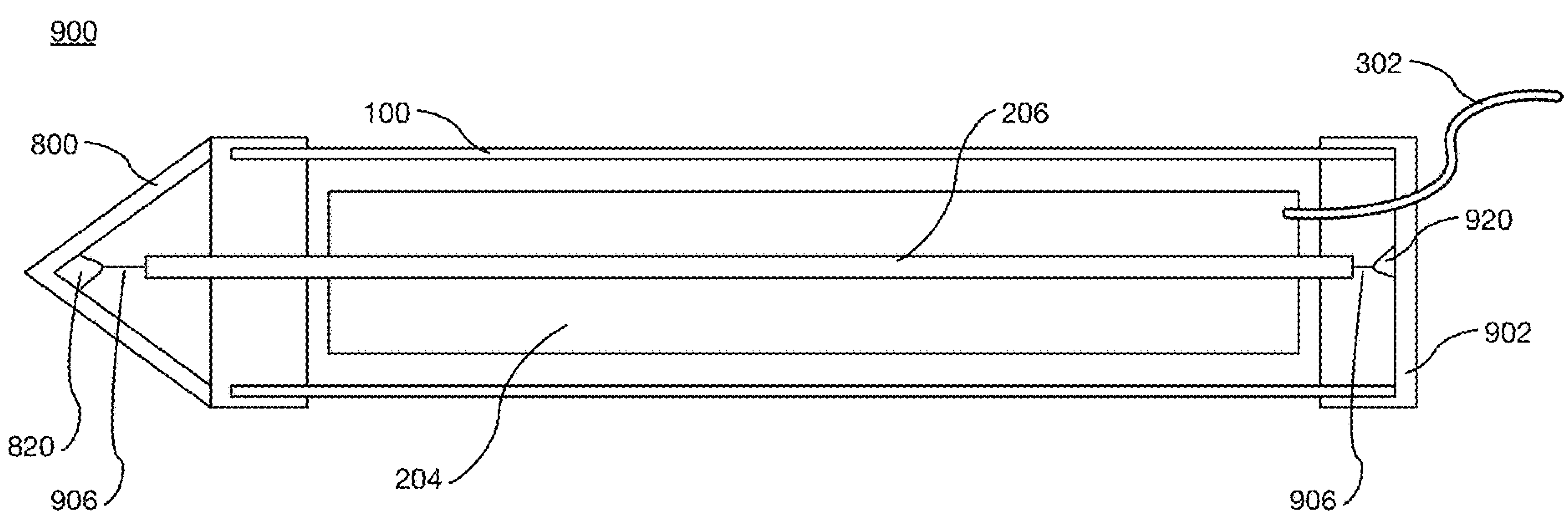
(57) **ABSTRACT**

A deployable, linear explosive structure includes a split tube, an explosive coupled to the split tube, and a fragmentable or non-fragmentable projectile disposed with respect to the explosive. The split tube can be rolled into a non-deployed state in which the split tube has a flat, rolled profile. The split tube also can be deployed from the non-deployed state to a deployed state in which the split tube is extended along its length and has a curved cross-section along its length. The split tube provides support of the explosive structure in the deployed state. The split tube also provides smaller storage and transportation volume for the explosive structure when rolled in the non-deployed state.

22 Claims, 11 Drawing Sheets



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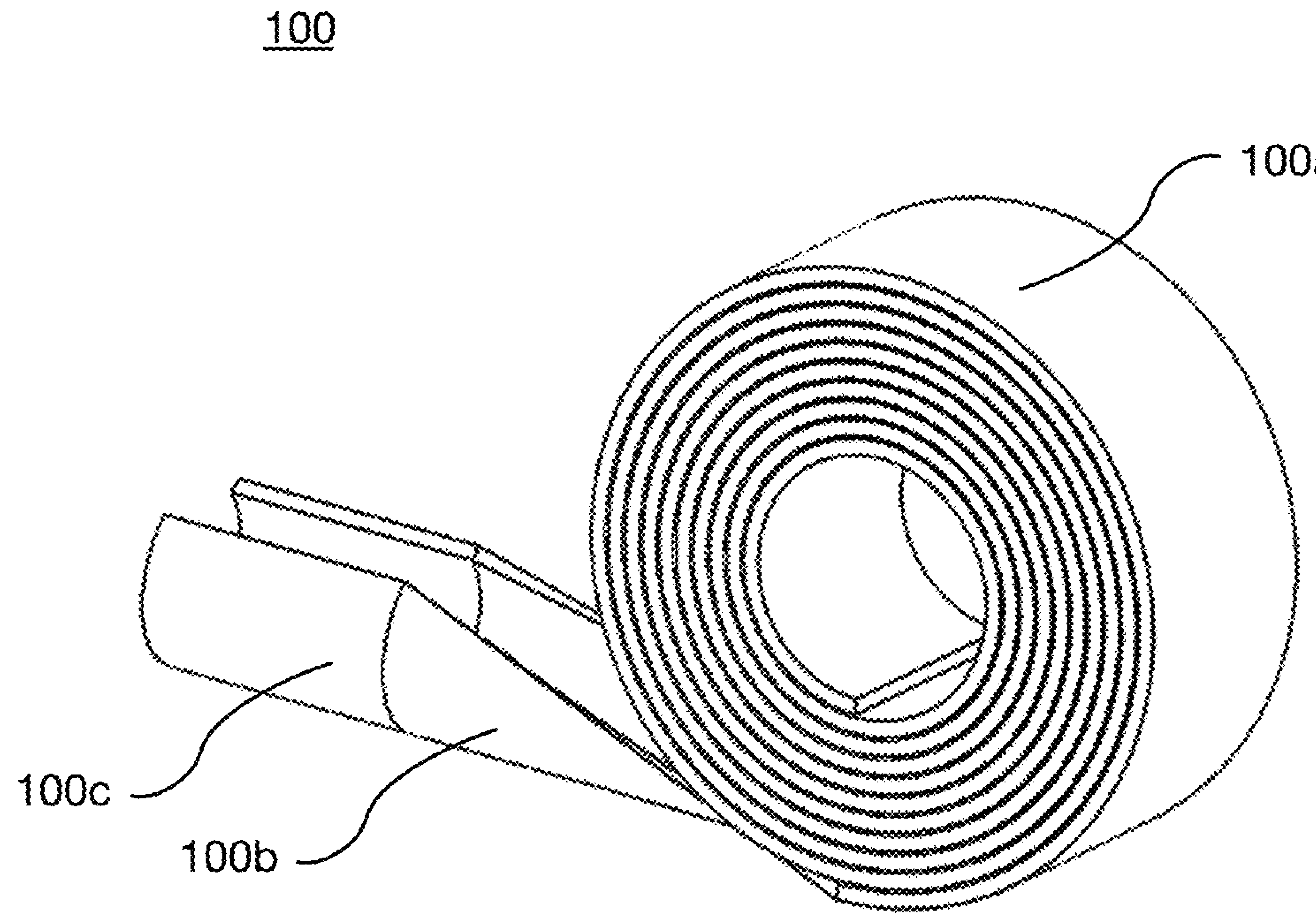

Figure 1A

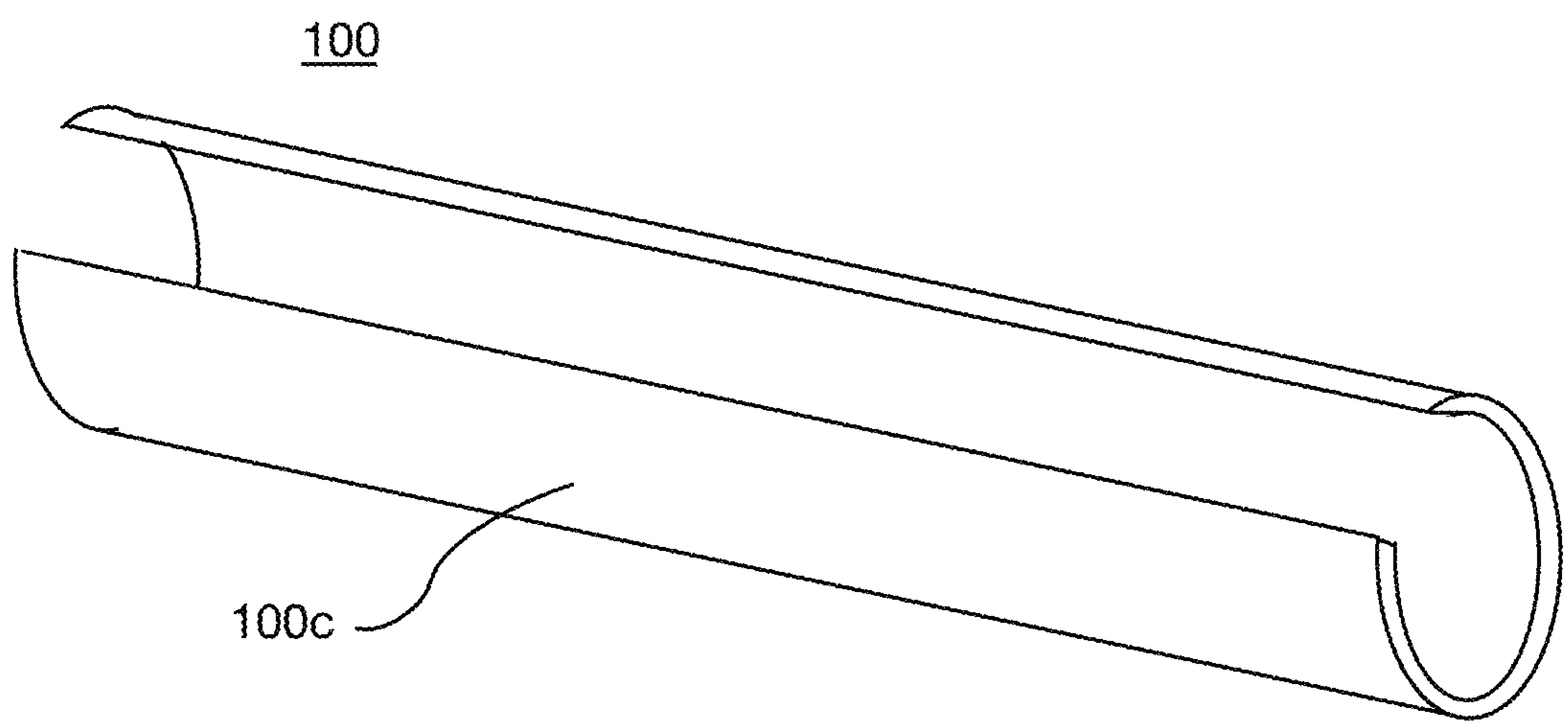

Figure 1B

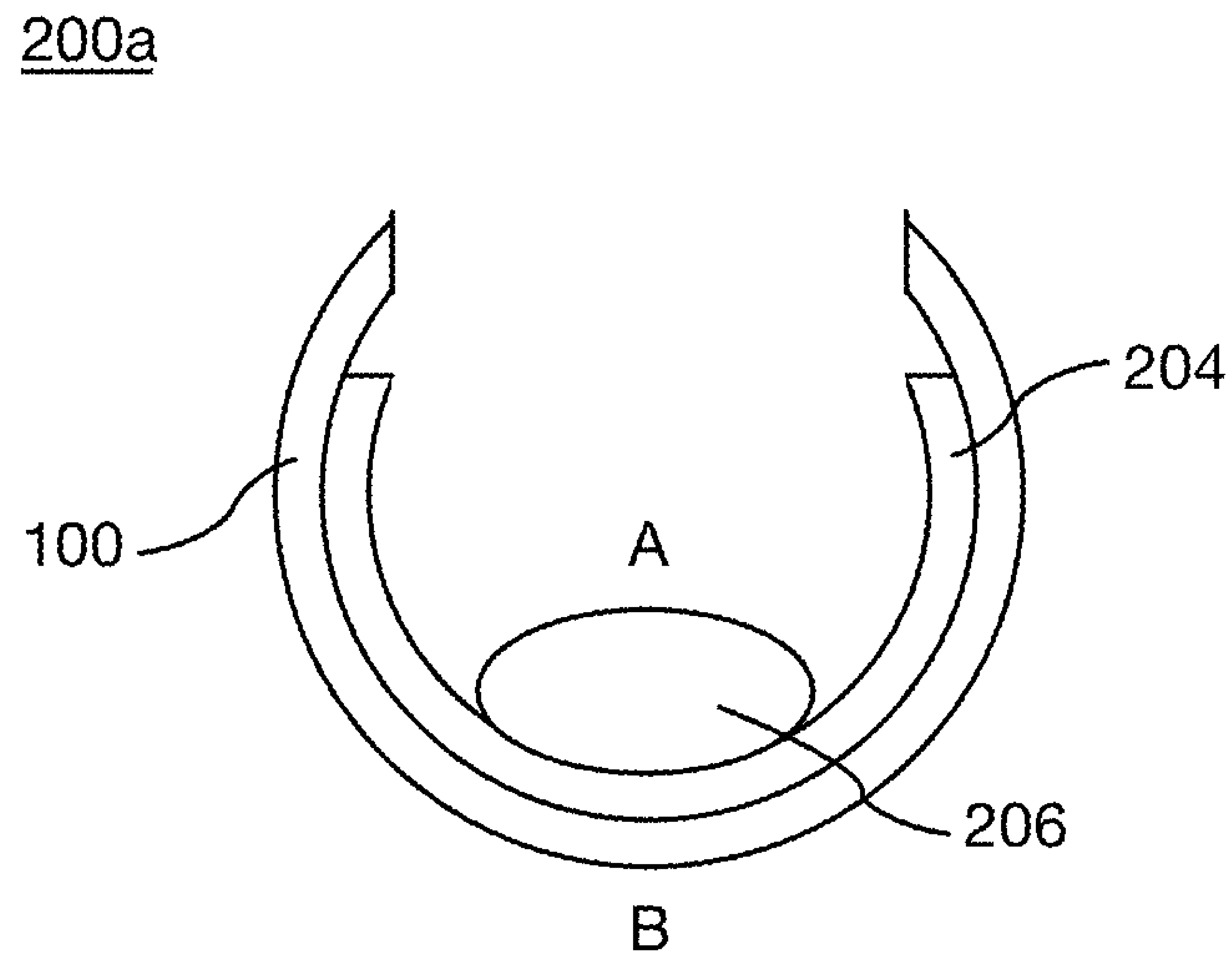

Figure 2A

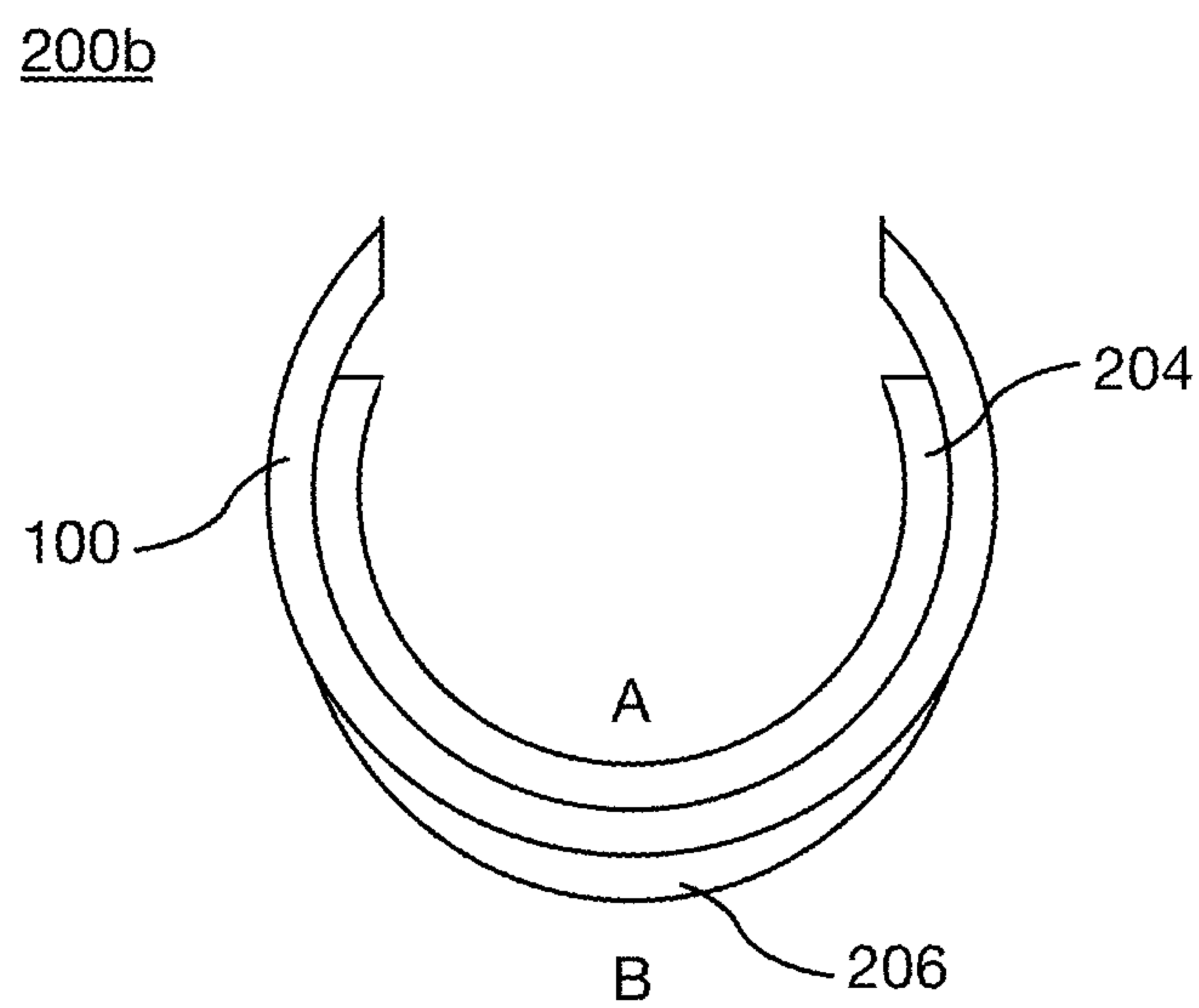

Figure 2B

200c

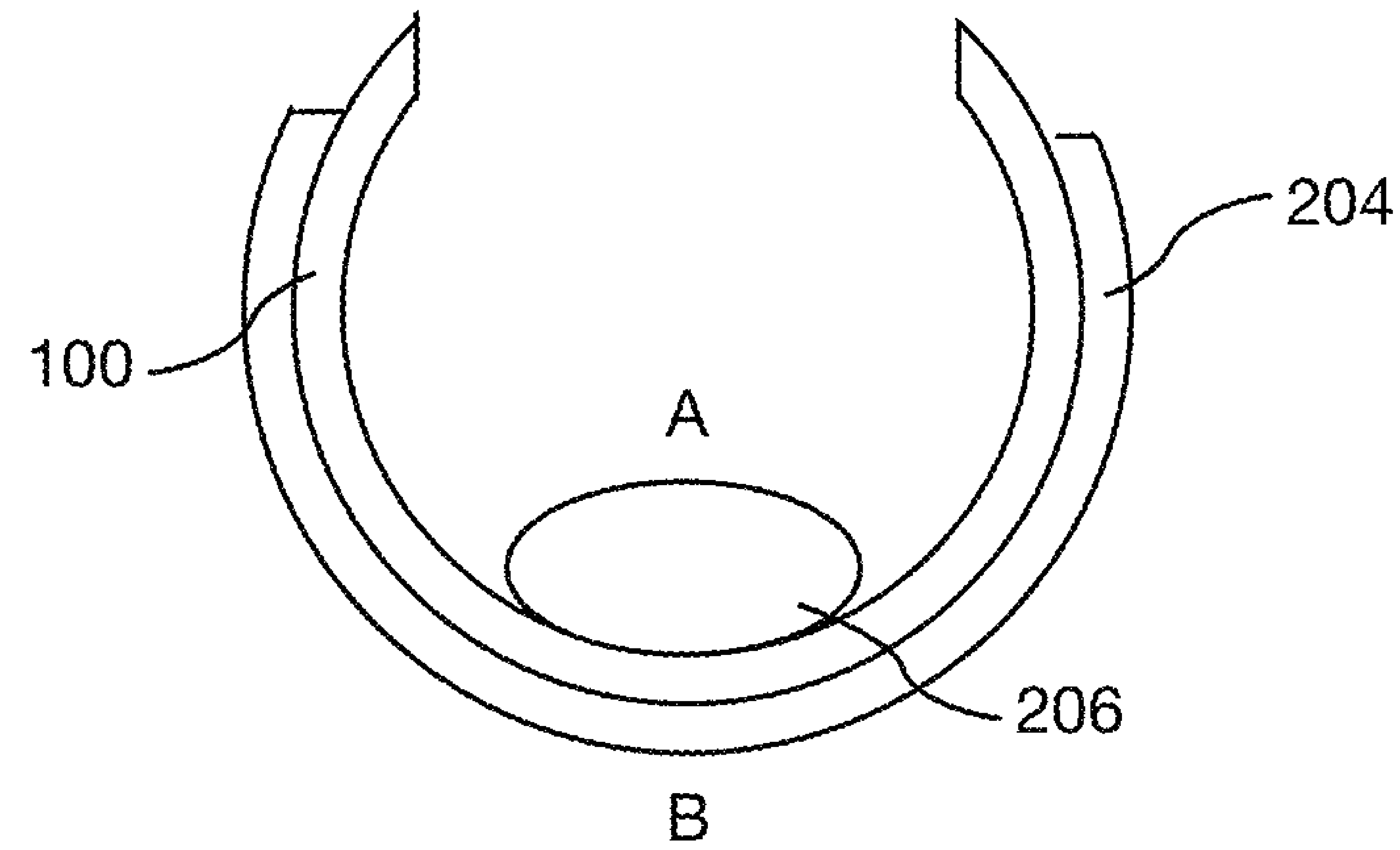

Figure 2C

200d

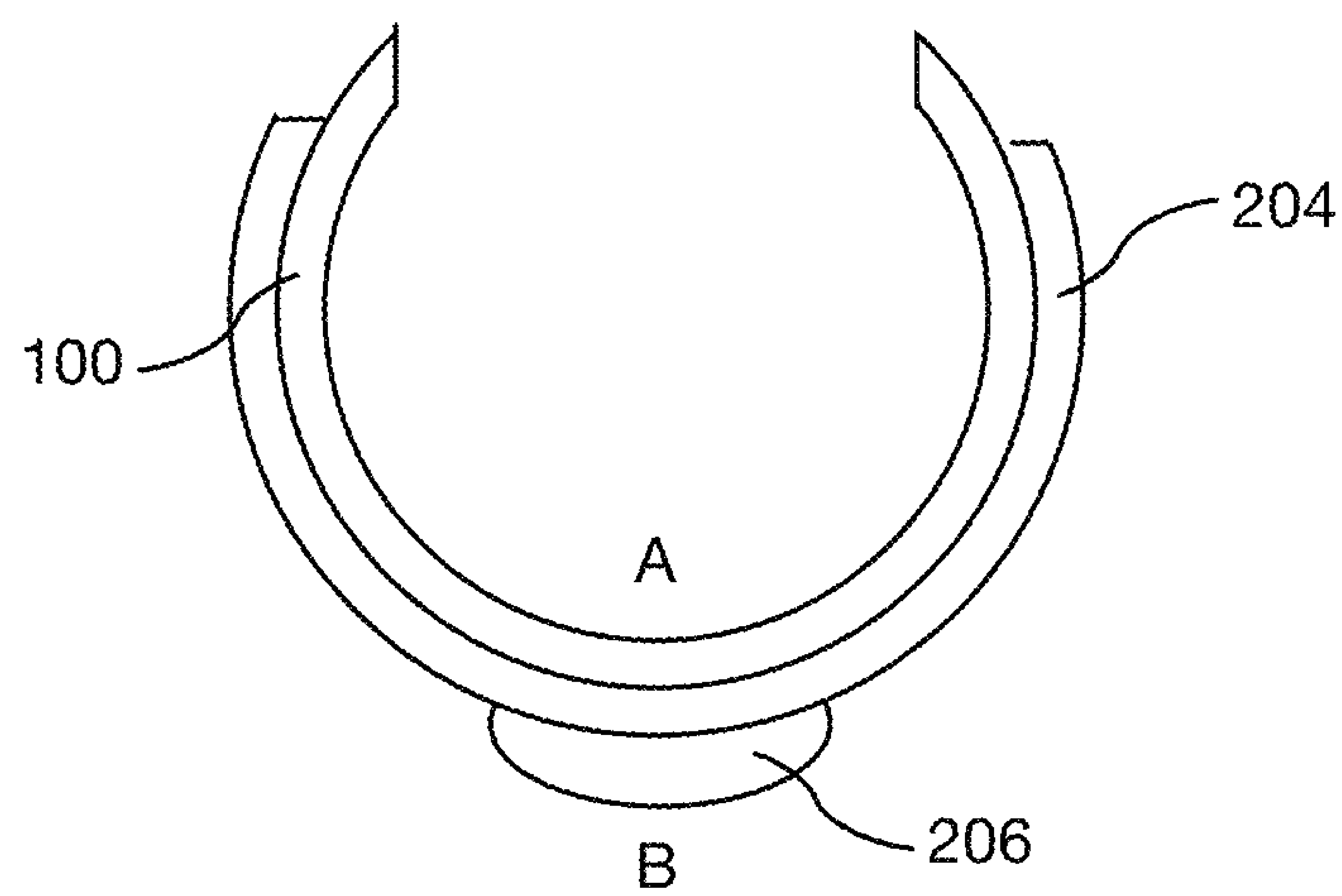

Figure 2D

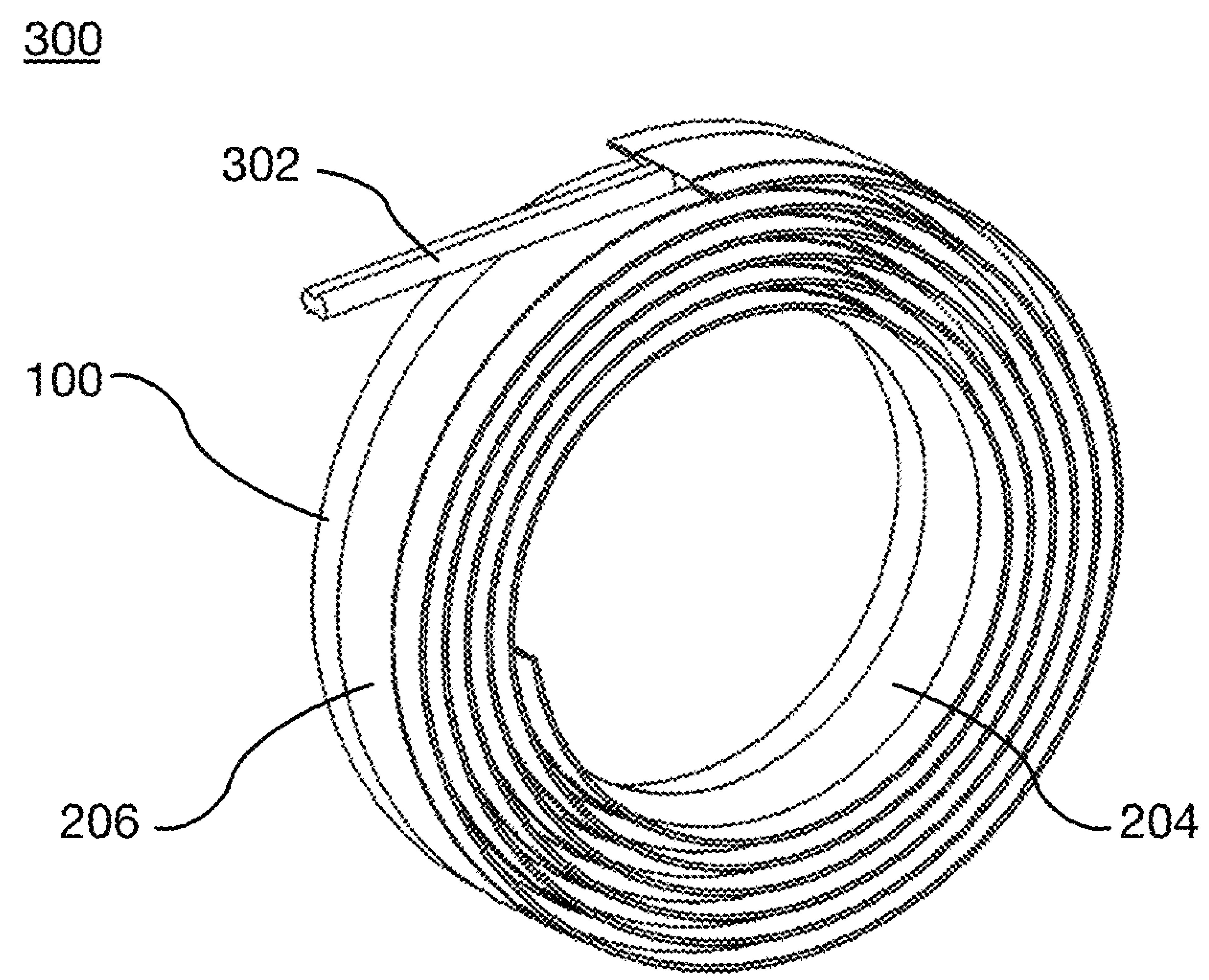

Figure 3A

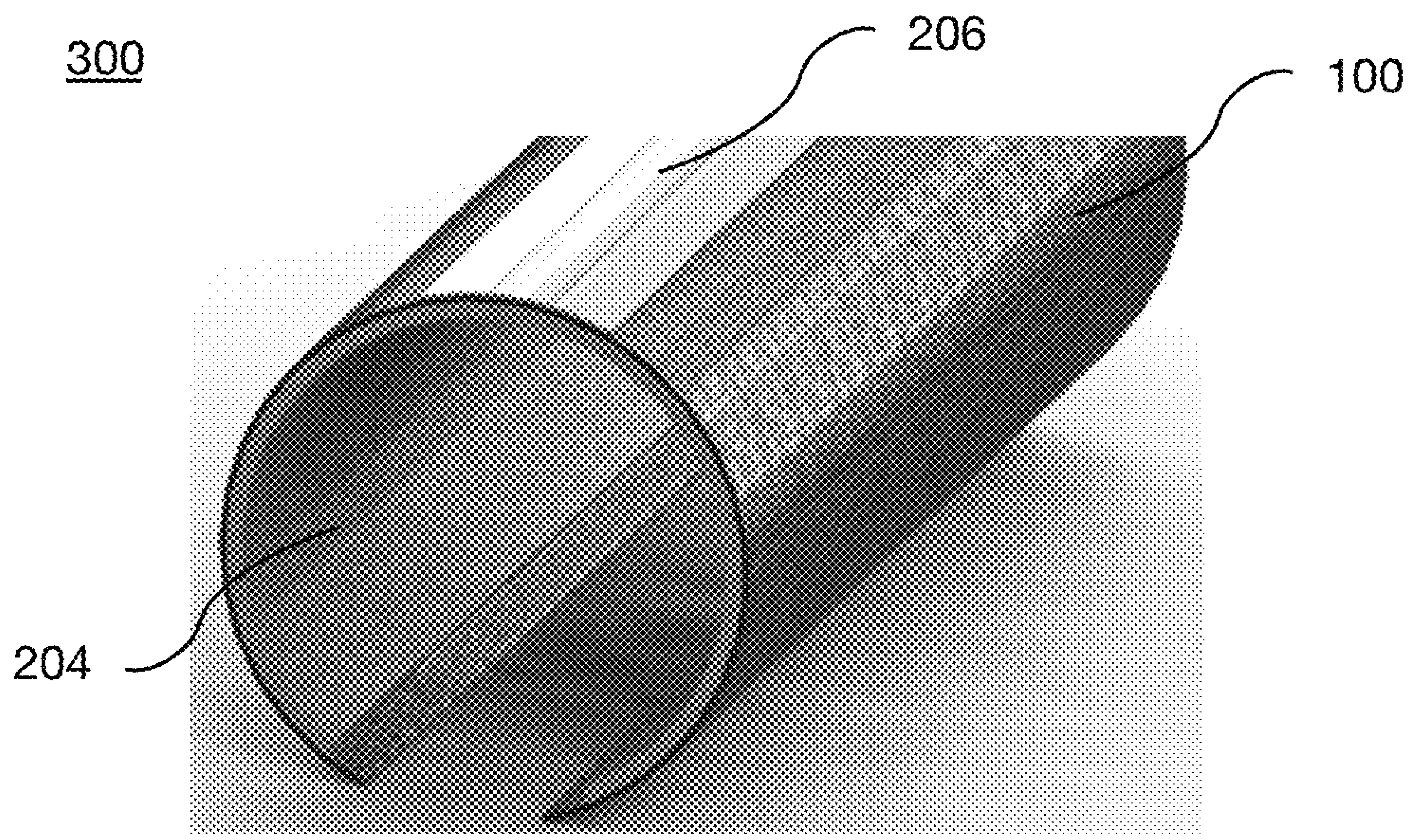

Figure 3B

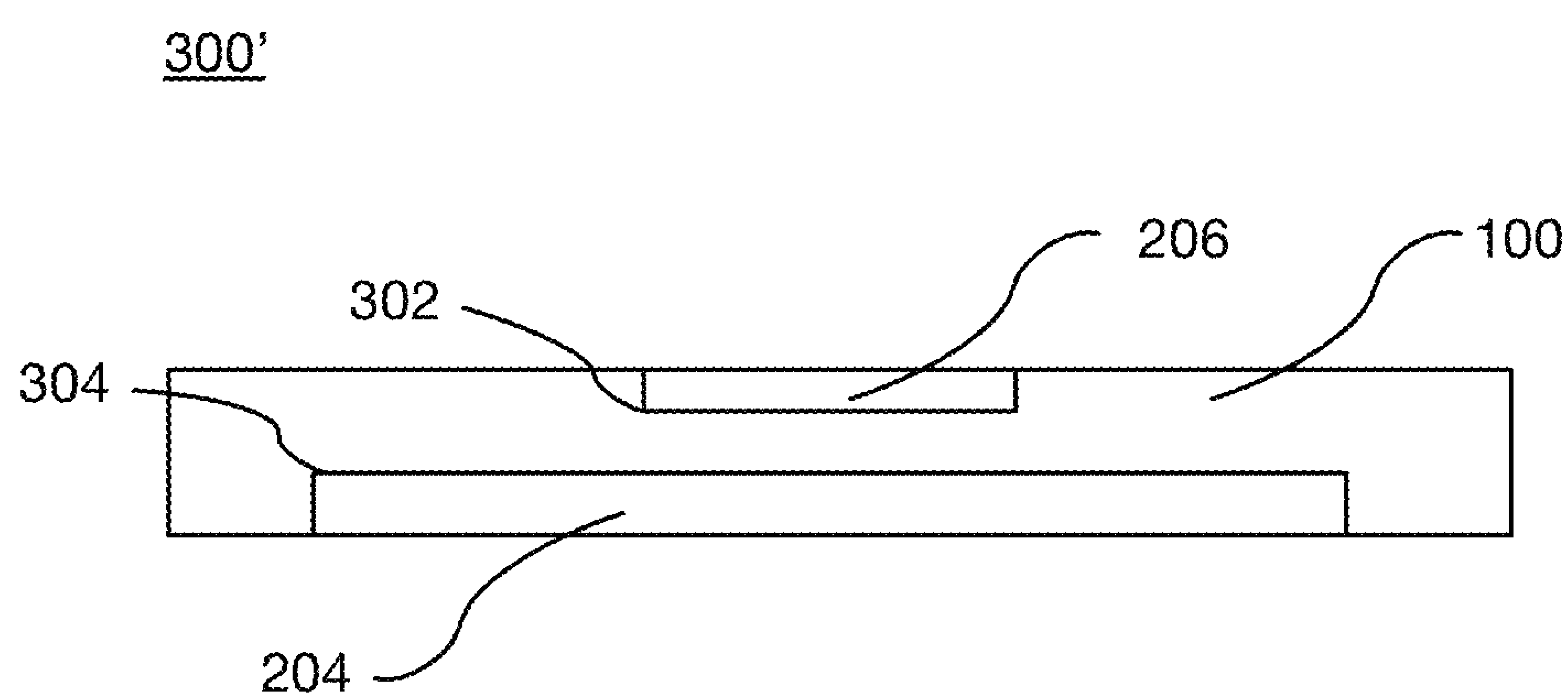

Figure 3C

400

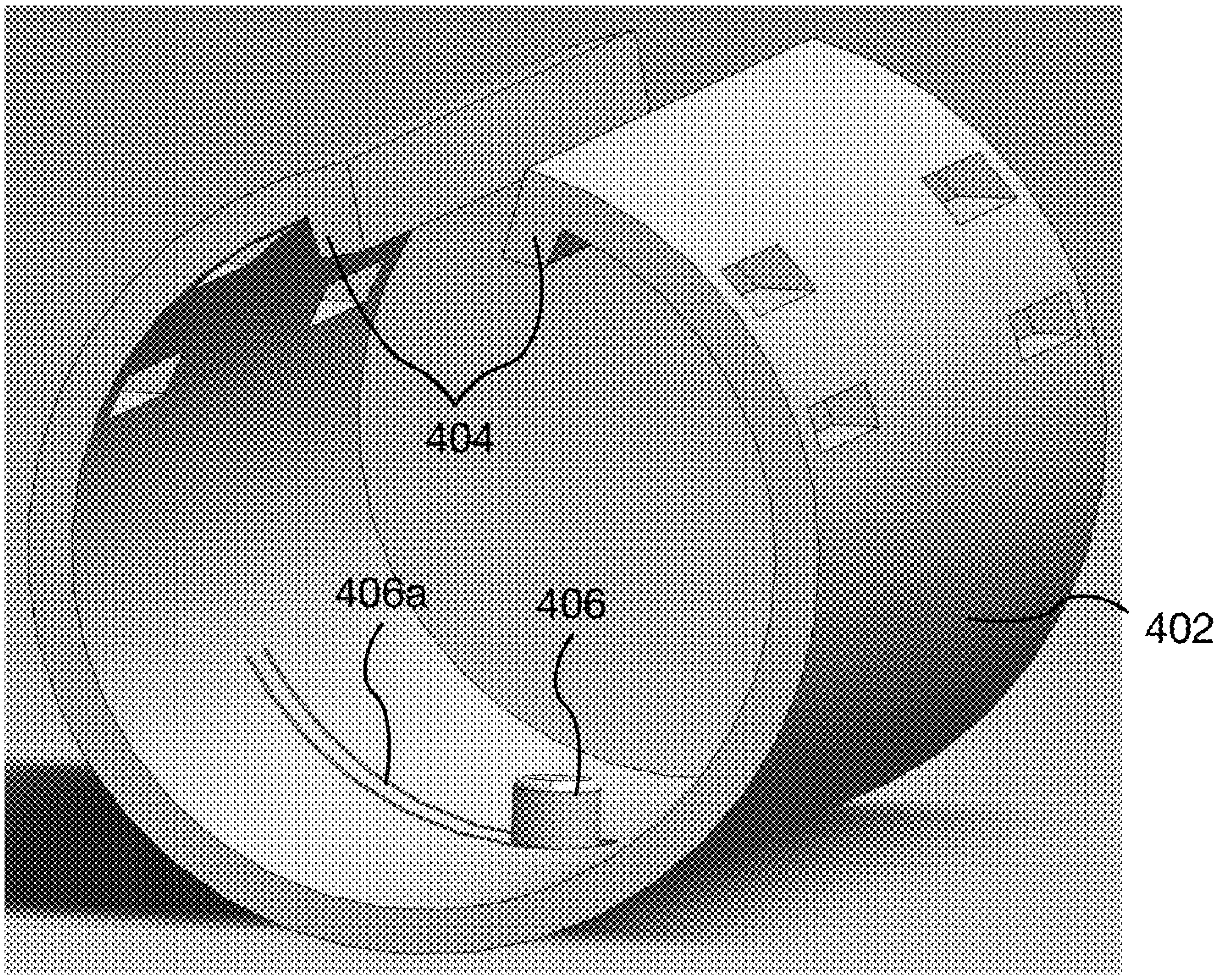

Figure 4

500

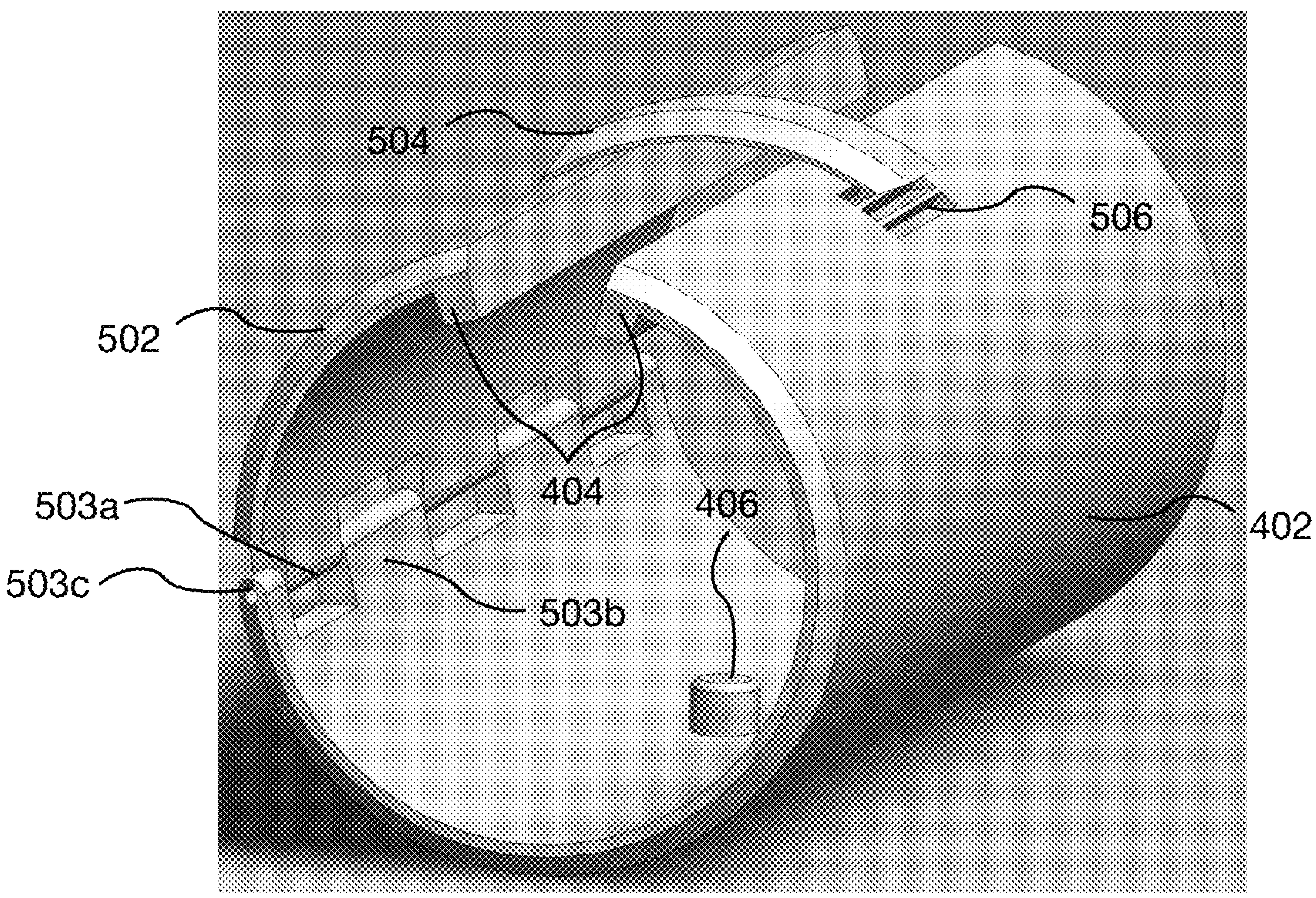

Figure 5

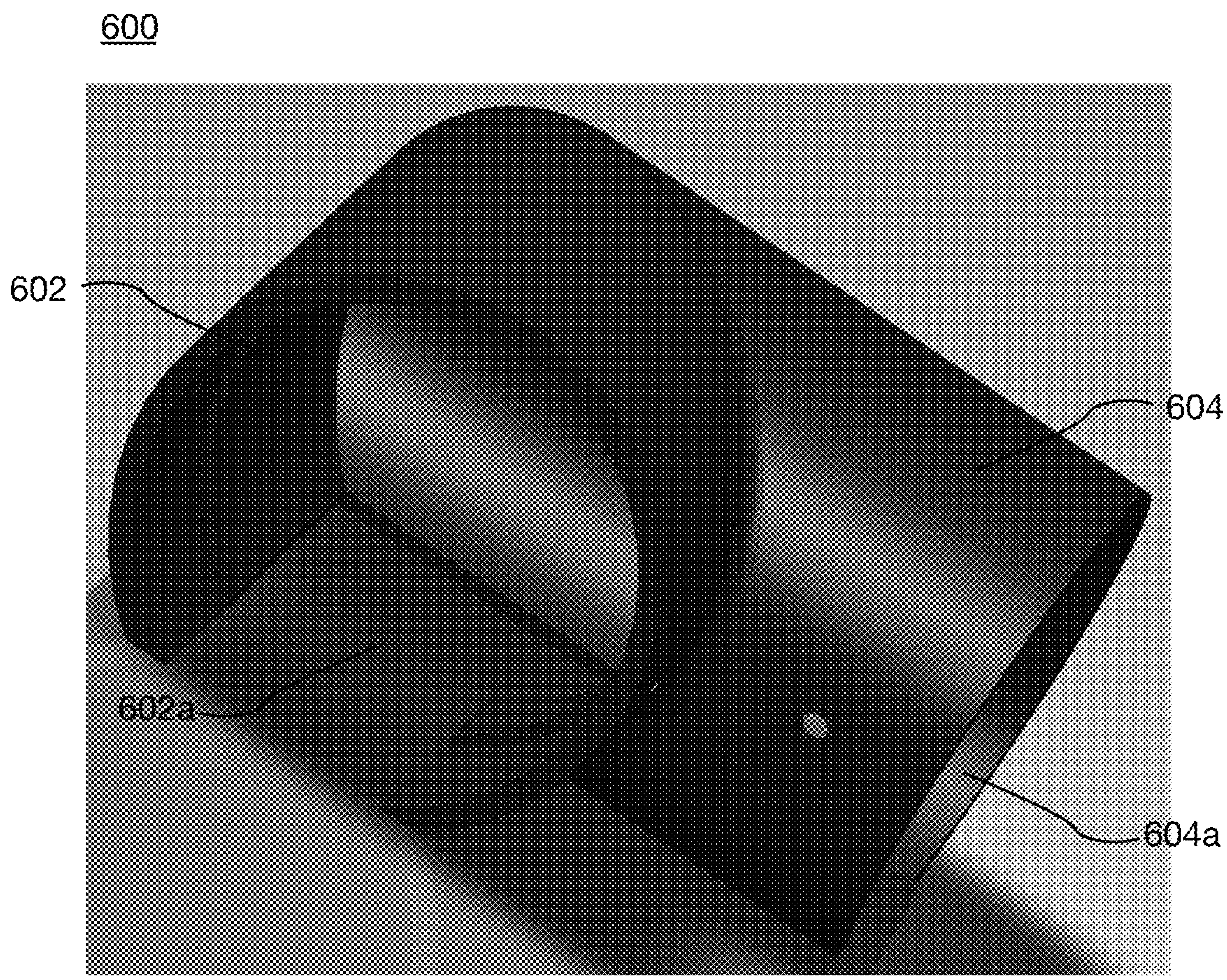

Figure 6

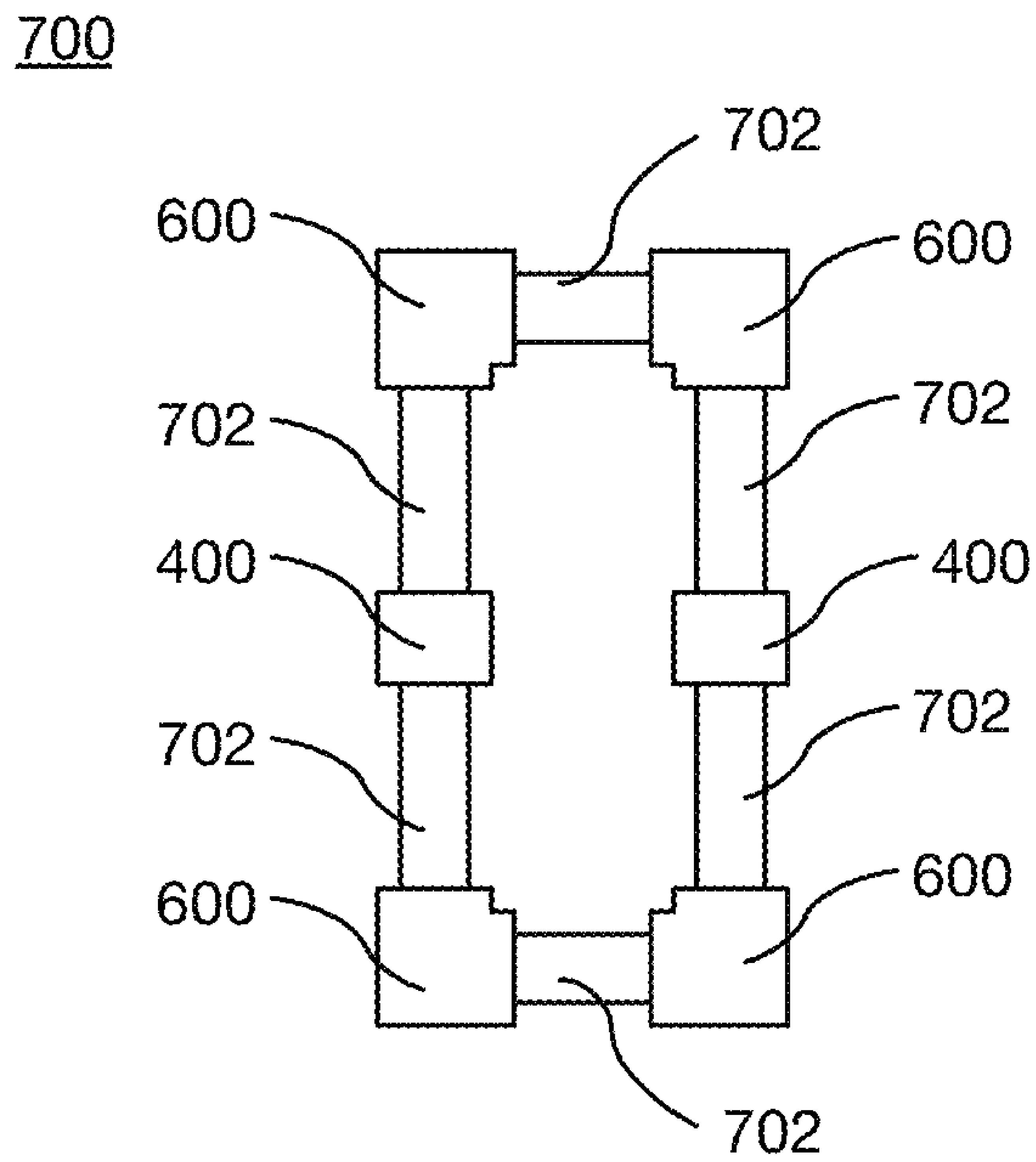

Figure 7A

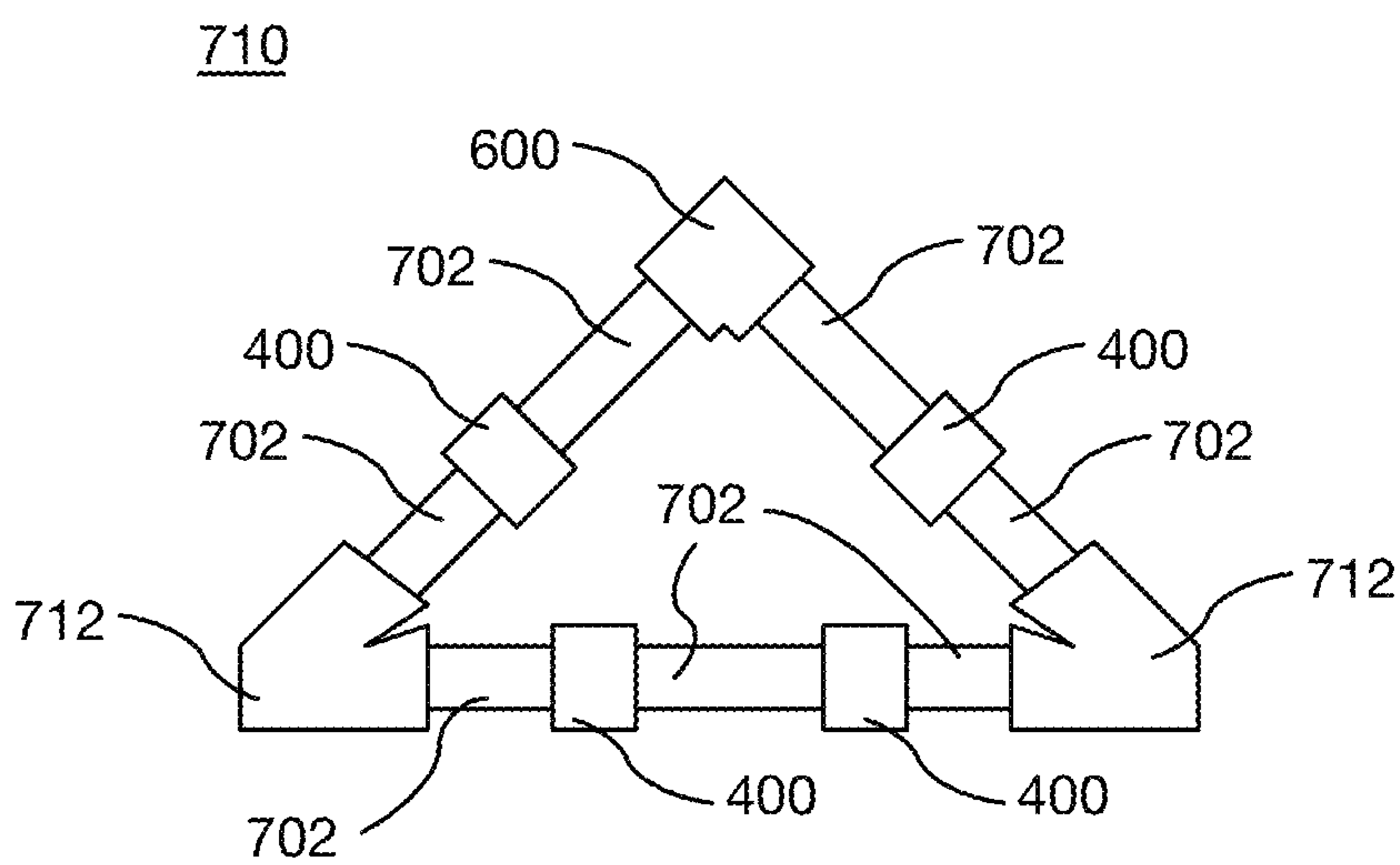

Figure 7B

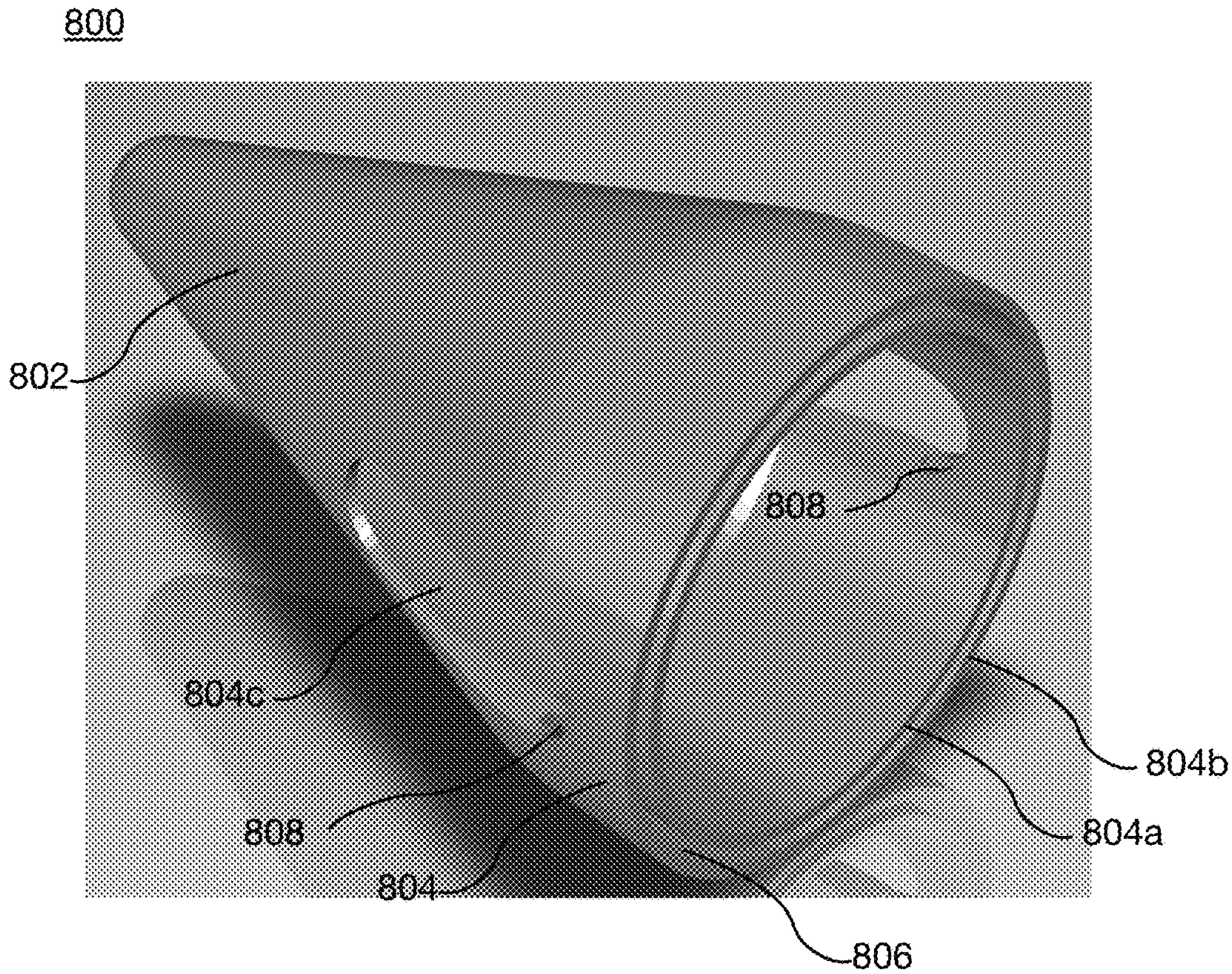

Figure 8A

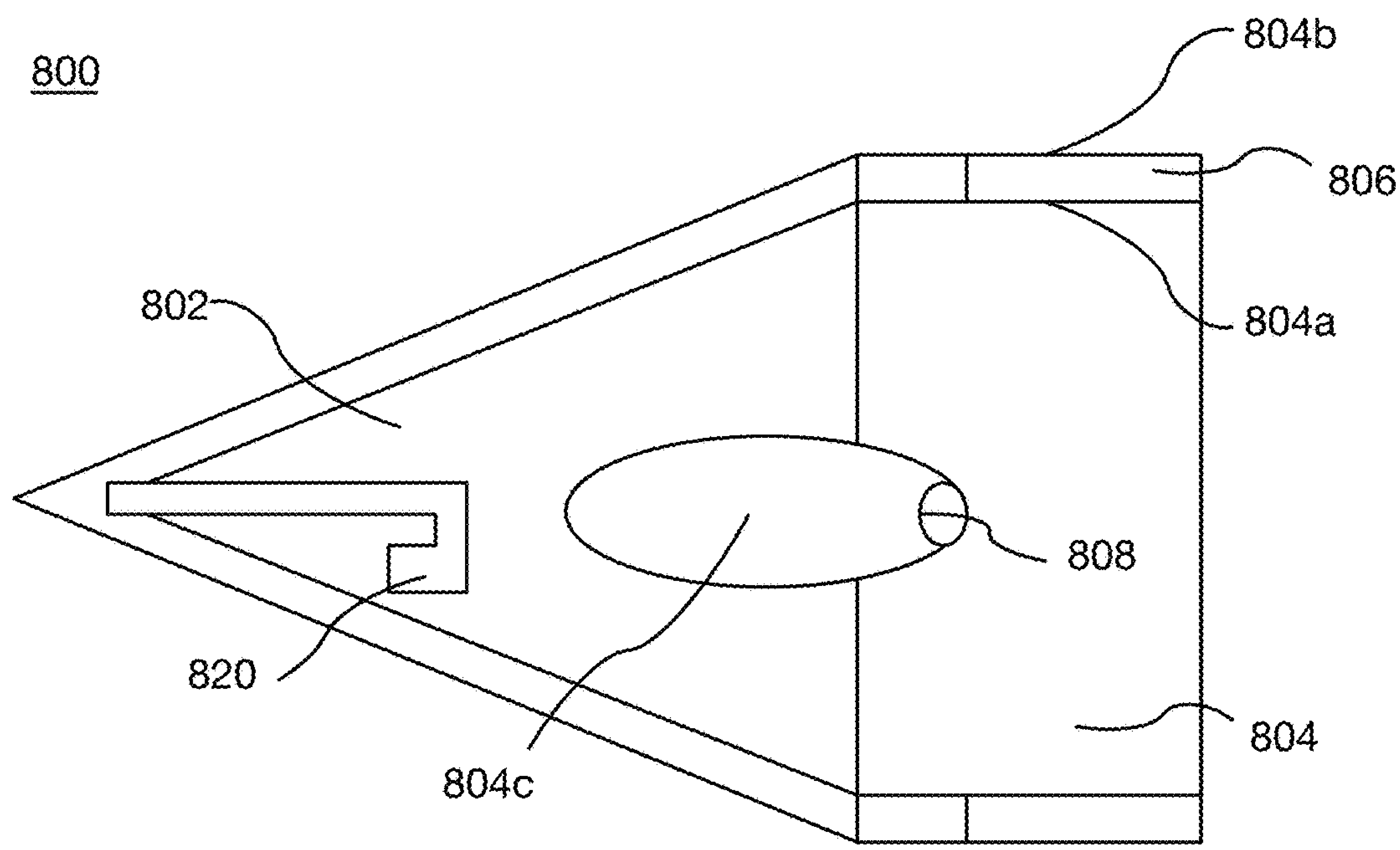

Figure 8B

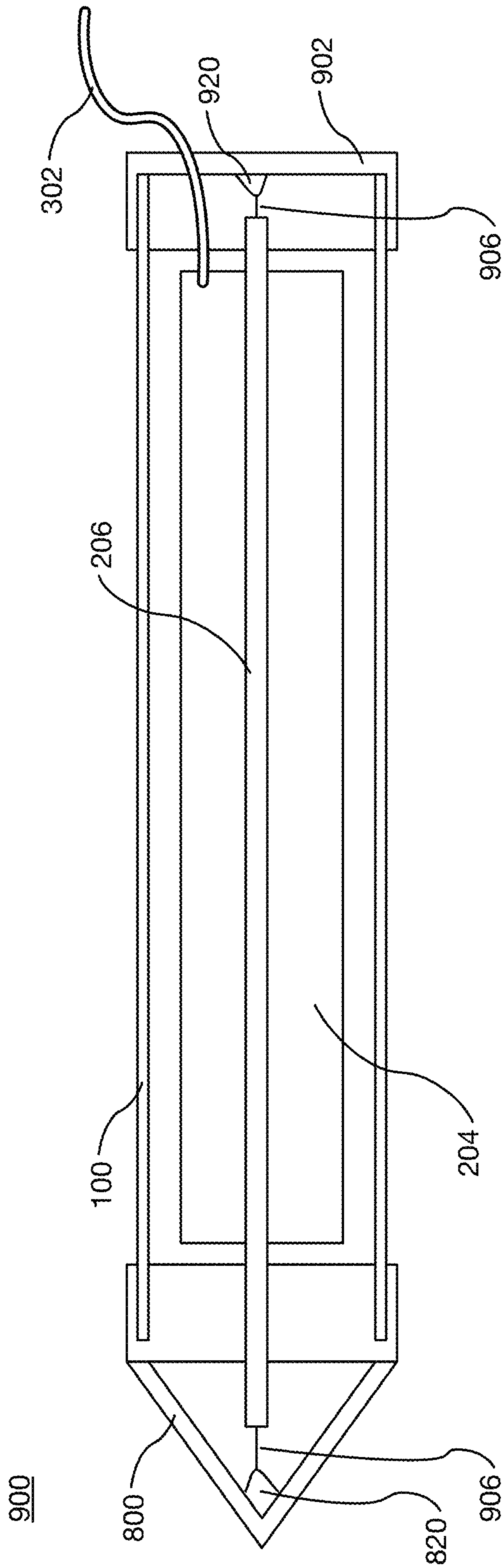

Figure 9

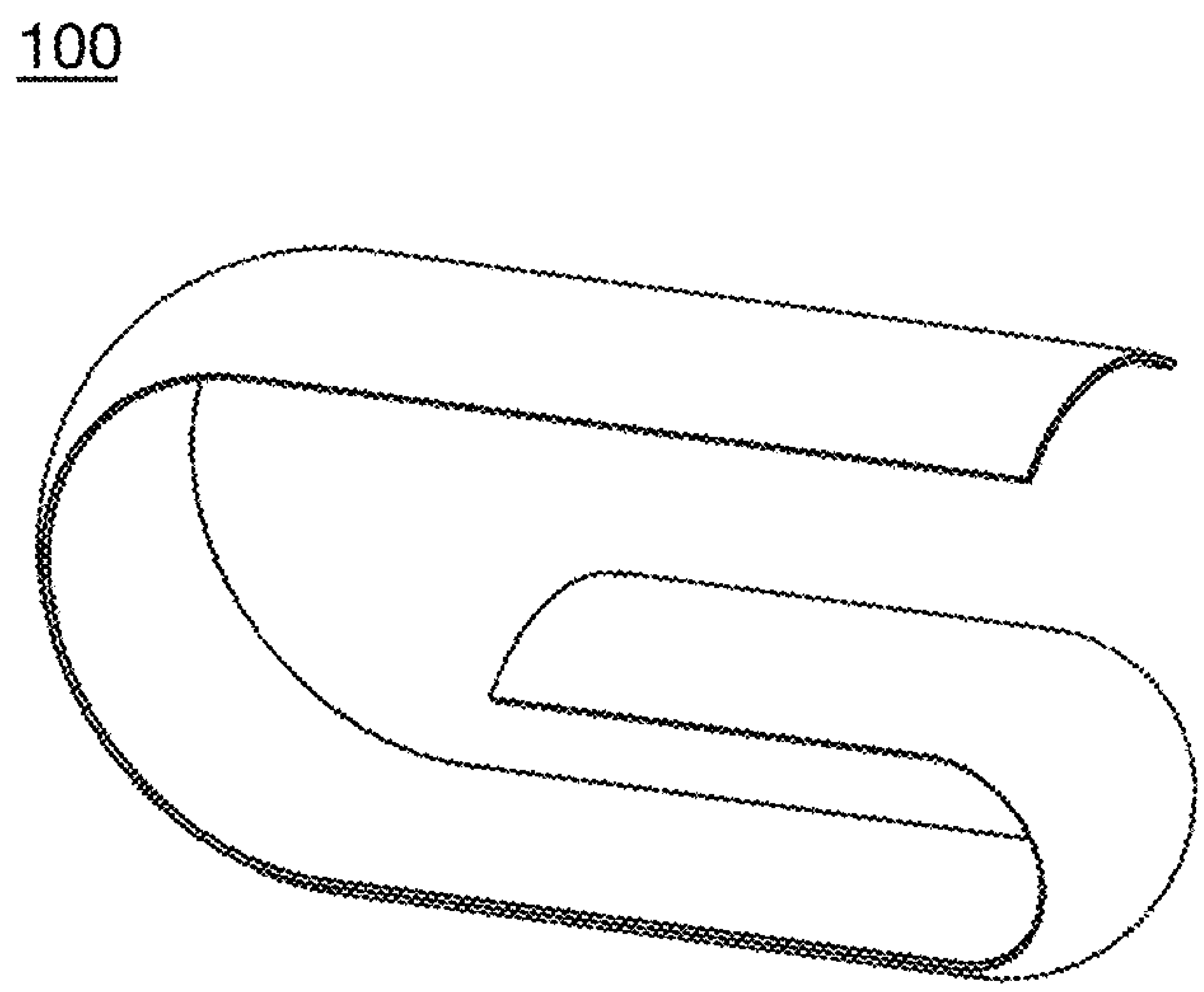

Figure 10A

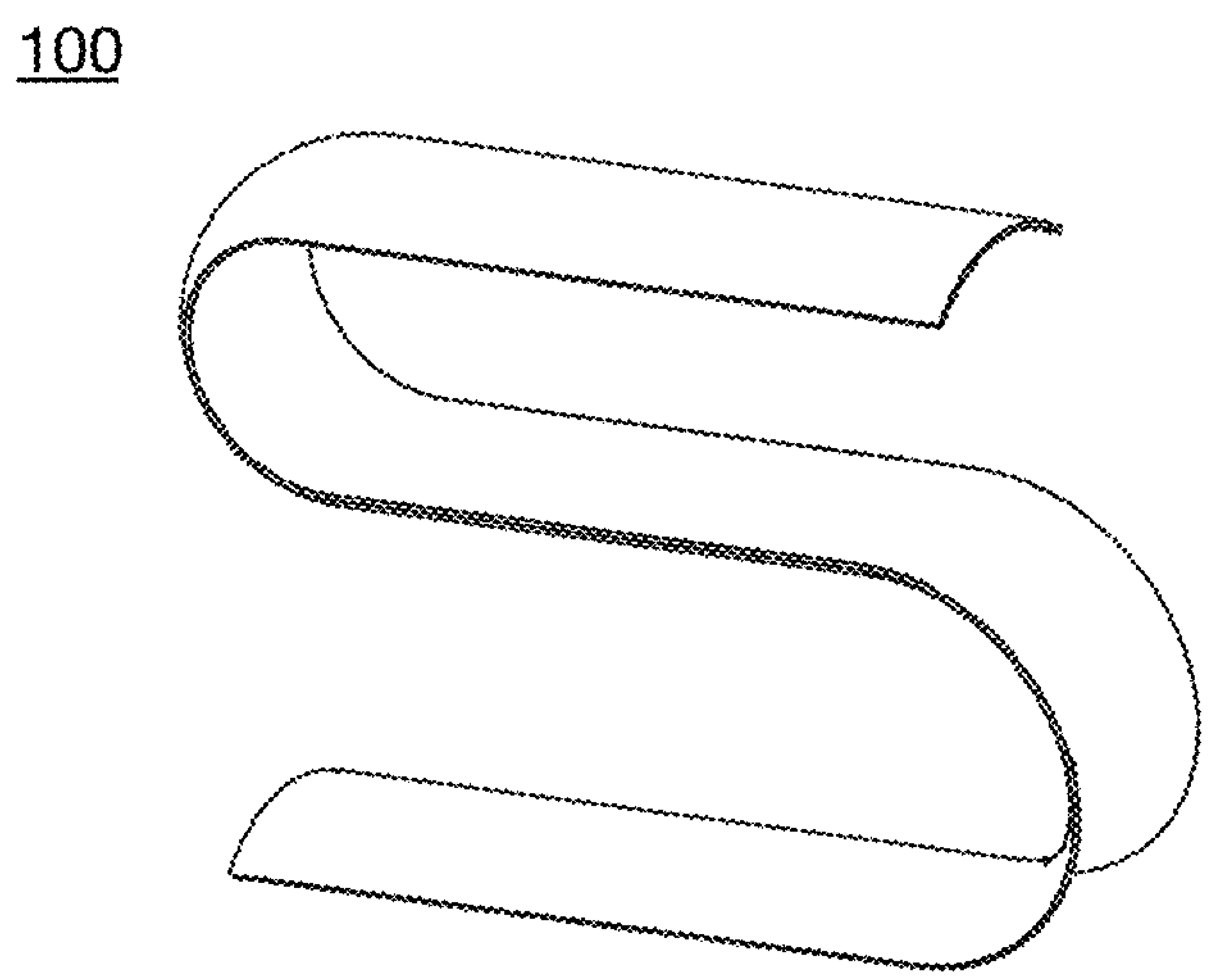

Figure 10B

PROJECTILE-PROPELLING EXPLOSIVE STRUCTURE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application No. 63/285,744 filed Dec. 3, 2021 and titled "Explosive Structure." The entire contents of the above-identified priority application are hereby fully incorporated herein by reference.

TECHNICAL FIELD

The technology disclosed herein relates to an explosive structure, and, more particularly, to a deployable explosive structure that propels a projectile in a directed action when detonated.

BACKGROUND

Conventional explosive charges used to clear obstacles are bulky. For example, a conventional pole charge is formed from one or more pipe sections, where at least one of the pipe sections contains an explosive. Each pipe section typically is five feet long. These long sections of pipe must be transported to a desired location for detonation, and a soldier must hand-carry the pipe sections the "last mile" to the target. Such long pipe sections do not fit within standard packs, and the bulk of the pipe sections makes them difficult to carry. Additionally, conventional pole charges are limited in their application, whereby they are not suitable to be adapted to other uses, such as troop defense.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of a split tube in a rolled, non-deployed state.

FIG. **1**B is a perspective view of a split tube in the linear, deployed state.

FIG. **2**A is a cross-sectional view of an explosive structure comprising an explosive and a projectile disposed on and inside of a split tube.

FIG. **2**B is a cross-sectional view of an explosive structure comprising an explosive disposed on the inside of the split tube and a projectile disposed on an outside of the split tube.

FIG. **2**C is a cross-sectional view of an explosive structure comprising an explosive disposed on the outside of the split tube and a projectile disposed on the inside of the split tube.

FIG. **2**D is a cross-sectional view of an explosive structure comprising an explosive and a projectile disposed on the outside of the split tube.

FIG. **3**A is a perspective view of an explosive structure in the rolled, undeployed state.

FIG. **3**B is a perspective view of an explosive structure in the linear, deployed state.

FIG. **3**C is a cross-sectional view of an explosive structure comprising a split tube profile that envelops the explosive and the projectile to provide an overall flat profile for the explosive structure.

FIG. **4** is a perspective view of a straight connector for connecting two explosive structures in an end-to-end configuration.

FIG. **5** is a perspective view of a hinged, straight connector for connecting two explosive structures in an end-to-end configuration.

FIG. **6** is a perspective view of an angled connector for connecting two explosive structures in an angled configuration.

FIG. **7**A is a plan view of a rectangular configuration comprising multiple explosive structures connected by multiple straight connectors and multiple angled connectors.

FIG. **7**B illustrates a plan view of a triangular configuration comprising multiple explosive structures connected by multiple straight connectors and multiple angled connectors.

FIG. **8**A is a perspective view of a nose cone for an explosive structure.

FIG. **8**B is a cross-sectional view of the nose cone for an explosive structure.

FIG. **9** is a cross-sectional view of an explosive structure comprising a suspended projectile.

FIG. **10**A is a perspective view of a split tube that is rolled in a flattened roll as its undeployed state.

FIG. **10**B is a perspective view of a split tube that is folded in a serpentine pattern as its undeployed state.

DETAILED DESCRIPTION

The technology described herein relates to a deployable, linear explosive structure that propels a projectile in a desired direction. The deployable, linear explosive structure includes a split tube, an explosive coupled to the split tube, and a fragmentable or non-fragmentable projectile disposed with respect to the explosive. The split tube can be rolled into a non-deployed state in which the split tube has a flat, rolled profile. The split tube also can be deployed from the non-deployed state to a deployed state in which the split tube is extended along its length and has a curved cross-section along its length. The split tube provides support of the explosive structure in the deployed state. The split tube also provides smaller storage and transportation volume for the explosive structure when rolled in the non-deployed state.

The explosive is coupled to either side of the split tube. For example, the explosive is coupled to an "inside" of the split tube. In this case, the explosive is disposed on the concave side of the curved cross-section of the split tube. The explosive also can be coupled to an "outside" of the split tube. In that case, the explosive is disposed on the convex side of the curved cross-section of the split tube.

The projectile is disposed on the explosive structure relative to the explosive such that detonation of the explosive propels the projectile in the desired direction. Various configurations of the projectile relative to the explosive are suitable. For example, if the explosive is disposed on the inside of the split tube, the projectile also may be disposed inside the split tube, or the projectile may be disposed on the outside of the split tube. In each case, the projectile may be coupled directly to the explosive and/or the split tube or may be suspended inside or outside of the split tube.

Detonation of the explosive propels the projectile away from the explosive in a desired direction.

Exemplary projectile-propelling explosive structures and components according to various aspects of the technology discussed herein will now be described with reference to the figures. Like numerals represent like (but not necessarily identical) elements throughout the figures.

FIGS. **1**A and **1**B illustrate a split tube **100** that forms part of the explosive structure described herein. FIG. **1**A is a perspective view of the split tube **100** in a rolled, non-deployed state, as shown by the rolled section **100***a* of the split tube **100**. The rolled, non-deployed state **100***a* of the split tube **100** has a flat profile. As shown in FIG. **1**A, the split tube comprises a flat, rolled profile **100***a* in the undeployed state, and a curved, linear profile **100**c in the deployed state, separated by a transition zone **100**b where the split tube gradually transitions from the rolled, undeployed state **100**a to the linear, deployed state **100**c. When fully undeployed, substantially all of the split tube comprises the rolled, flat profile **100**a. When fully deployed, substantially all of the split tube comprises the curved, linear profile **100**c.

FIG. **1**B is a perspective view of a split tube **100** in the linear, deployed state **100**c. The linear, deployed state **100**c of the split tube **100** has a curved, linear profile.

The split tube **100** may be any suitable tubular structure. A "split tube" is a tubular structure that is not a completed tube because edges of the tubular structure are not connected. As shown in FIGS. **1**A and **1**B, the split tube **100** has a cross-section comprising approximately eighty percent of a full circle or other tubular structure. Any suitable diameter of the split tube **100** may be utilized to provide desired support for an explosive and a projectile when in the linear, deployed state **100**c. For example, more or less of a diameter may be utilized as desired. The split tube can comprise more than eighty percent of a full tube, and may comprise more than 100% of a full tube. For more than 100% of a full tube, the edges **100**d of the split tube **100** will overlap to complete a full tubular shape. The split tube **100** also can comprise less than eighty percent of a full tube, even as little as 10% of a full tube, as long as the linear, deployed shape has a curved cross-sectional profile.

The split tube **100** may be formed of any suitable material, such as metal, plastics, composites, or any other suitable material or combinations thereof.

The split tube **100** may be, for example, a bistable structural tape comprising an undeployed state **100**a and a deployed state **100**c. The bistable tape has a rolled, flat transverse profile in the undeployed state **100**a, and the bistable tape has a linear, curved profile in the deployed state **100**c. The bistable tape is stable in the undeployed state **100**a and in the deployed state **100**c, and the bistable tape is unstable when between states such that transitioning one end of the bistable tape from the rolled shape to the linear shape places the bistable tape in an unstable state causing the bistable tape to self-deploy to the deployed state **100**c.

For a split tube **100** that is a bistable tape, the bistable tape can be made from a carbon fiber composite, fiberglass, or other suitable material or combinations thereof. The two states in which the bistable tape is stable are: (a) when substantially the entire bistable tape is disposed in an Archimedean roll (i.e., the undeployed state **100**a) and (b) when substantially the entire bistable tape extends linearly (i.e., the deployed state **100**c). If the bistable tape is between these two stable states, (i.e., a portion of the tape is rolled up and a portion of the tape extends linearly or is partially deployed), the energy stored in the tape is automatically applied to transition the tape towards one of the two stable states. Since one of the two stable states is the undeployed state **100**a in which the bistable tape is disposed in an Archimedean spiral, this use of a bistable tape may avoid the need for a restraining device to maintain the undeployed state **100**a. To elaborate, one of the stable states of the bistable tape is the Archimedean spiral or roll. As such, the bistable tape will remain in the Archimedean spiral or roll until action is taken to deploy the bistable tape. Specifically, once a portion of the bistable tape is deployed by moving the outer end of the tape away from the roll so that the portion of the tape extends linearly and adopts a curved profile, the remainder of the bistable tape will self-deploy to adopt the fully deployed configuration shown in FIG. **1**B.

A bistable tape also can be used when the undeployed state **100**a is a "flattened" roll or is folded in a serpentine pattern, as depicted in FIGS. **10**A and **10**B, respectively. However, a restraining device may be needed to maintain the bistable tape in an undeployed state that is a flattened roll or a serpentine fold. FIG. **10**A is a perspective view of a split tube **100** that is rolled in a flattened roll as its undeployed state. FIG. **10**B is a perspective view of a split tube **100** that is folded in a serpentine pattern as its undeployed state. In any of these undeployed states, releasing the potential energy of the bistable tape will cause the bistable tape to self-deploy into the linear, deployed state. As shown in undeployed states of FIGS. **10**A and **10**B, a portion of the split tube **100** is already transitioned to the deployed state. Accordingly, when a restraint is removed from the split tube **100**, the split tube **100** will fully self-deploy to the linear, deployed state.

In other examples, the split tube **100** may be a carpenter's tape without the properties of a bi-stable structural state. In the deployed state **100**c, the carpenter's tape extends linearly between the ends of the tape and has a transverse curve over the deployed length of the tape. That configuration gives the deployed tape beam-like characteristics, which allow the tape to be supported at one end and to extend a considerable distance to a free or unsupported end. A carpenter's tape also can be rolled from one end to the other end (producing an Archimedean spiral roll) with the rolling resulting in the transverse curve in the tape being removed as the rolling operation progresses, thereby producing a flat, rolled tape. A carpenter's tape can also be folded so as form a "flattened" roll or folded to follow a serpentine path. In either case, linear sections of tape, which each have the noted transverse curve, are separated from one another by a curved section that lacks the transverse curve. In the undeployed state **100**a, the carpenter's tape stores potential energy that, if applied, causes the tape to transition from the undeployed state **100**a (or from the flattened roll or folded serpentine pattern undeployed states) to or towards the deployed state **100**c. In other words, the carpenter's tape is capable of self-deployment. If the carpenter's tape is a metal carpenter's tape (such as is found in a carpenter's measuring tape), the explosive structure comprising the carpenter's tape may use a restraint to hold the carpenter's tape in the undeployed state **100**a, regardless of whether the tape in the undeployed state **100**a is disposed in an Archimedean spiral, a "flattened" roll, or a folded serpentine pattern. Carpenter's tapes are typically formed from metal but may be formed from any suitable material.

A split tube **100** comprising a tape that is not bistable and is made from carbon fiber composite, fiberglass, or other suitable material can also be employed. The use of such a tape may utilize, like the carpenter's tape, a restraining mechanism to hold the tape in the undeployed state **100**a.

When using a carpenter's-type tape, deployment involves removing the restraining mechanism that is holding the structure in the undeployed state **100**a and allowing the carpenter's tape to unroll to the linear, deployed state **100**c. In contrast, when using a bistable tape and the bistable tape is in the rolled, undeployed state **100**a, the user displaces the outer end of the bistable tape away from the remainder of the bistable tape, thereby placing a small portion of the bistable tape in the deployed state **100**c. Once a sufficient amount of the bistable tape has been placed in the deployed state **100**c, the bistable tape will self-deploy towards the deployed state **100**c.

FIGS. **2**A-**2**D depict projectile-propelling explosive structures **200**a-**200**d incorporating the split tube **100** described with reference to FIGS. **1**A and **1**B. FIG. **2**A is a cross-sectional view of an explosive structure **200***a* comprising an explosive **204** and a projectile **206** disposed on and inside A of the split tube **100**. FIG. **2**B is a cross-sectional view of an explosive structure **200***b* comprising an explosive **204** disposed on the inside A of the split tube **100** and a projectile **206** disposed on an outside B of the split tube **100**. FIG. **2**C is a cross-sectional view of an explosive structure **200***c* comprising an explosive **204** disposed on the outside B of the split tube **100** and a projectile **206** disposed on the inside A of the split tube **100**. FIG. **2**D is a cross-sectional view of an explosive structure **200***d* comprising an explosive **204** and a projectile **206** disposed on the outside B of the split tube **100**.

As shown in FIGS. **2**A-**2**D, the explosive structures **200***a*-**200***d* comprise a split tube **100** (illustrated in the deployed position), an explosive **204** attached to the split tube **100**, and a projectile **206** disposed relative to the explosive **204**.

The explosive **204** may be any suitable explosive, for example, a sheet explosive, a cord explosive, a flexible explosive, a malleable explosive, or any suitable explosive material. It should be appreciated that, while each of explosive structures **200***a*-**200***d* illustrates the explosive **204** as being a sheet-type explosive **204**, other embodiments may employ multiple strands of explosive **204** or may employ a different type of flexible explosive **204**, such as detonating cord or other suitable explosive **204**. One example of a sheet-type explosive is DETASHEET® explosive. The sheet-type explosive facilitates the flat shape of the split tube **100** when the explosive structure is in the rolled, undeployed state **100***a*. Using bulkier, non-uniform, and/or non-flat explosives **204** may result in a less uniformly flat shape of the split tube **100** of the explosive structure in the rolled, undeployed state **100***a*. However, such explosives are still suitable for the explosive structures described herein.

As shown in FIGS. **2**A and **2**D, the projectile **206** is disposed adjacent to the explosive **204**. However, the projectile **206** may be disposed on a side of the split tube **100** that is opposite to the explosive **204**, as shown in FIGS. **2**B and **2**C. Additionally, the explosive **204** may be disposed on either side of the split tube **100**, as depicted in FIGS. **2**A-**2**D.

The projectile **206** may be laid on the explosive **204**. If desired, the projectile **206** may be adhered to the explosive structures **200***a*-**200***d*, for example, using an adhesive, such as a spray adhesive, tape, two-sided tape, or any suitable adhesive. The projectile **206** also may be coupled to the structure via mechanical devices, such as zip ties, string, paracord, rope, hooks, or other suitable device. The projectile also can be formed integrally with the split tube **100** or the explosive **204**.

The projectile **206** also may be laid loosely on the split tube **100** and/or the explosive **204**. In this case, the walls creating the inside of the split tube **100** hold the loosely laid projectile **206** in place. However, the projectile **206** also can be laid loosely on the outside of the split tube **100**.

Additionally, the projectile **206** may be suspended in proximity to the explosive **204** such that the projectile **206** does not touch the explosive **204** or the split tube **100** along a length of the projectile **206**, or such that only a portion of a length of the projectile **206** touches the explosive **204** or the split tube **100**. In one such example, bungee cords, or other suitable fastener cords, such as string, rope, wire, or paracord, are attached to each end of the projectile **206**. Each fastener cord has a hook or other suitable connector attached to an end of the fastener cord that is opposite to the end of the fastener cord attached to the projectile **206**. Then, the connectors are attached to opposite ends of the split tube **100** to suspend the projectile **206** between the sides of the split tube **100** and along a length of the split tube **100**. The connectors can be attached near the open edges of the split tube **100** to increase the height of the projectile **206** above the explosive **204**. The position of the connectors on the ends of the split tube **100** can be adjusted around the circumference of the split tube **100** to control a height of the projectile **206** above the explosive **204**. The split tube **100** can include the hooks and/or fastener cords attached to its ends, which may be connected directly to the projectile **206** or to the fastener cords attached to the projectile **206**.

The projectile **206** can be attached to the outside of the split tube **100** using the connectors as well, in which case the projectile **206** is disposed along an exterior length of the split tube **100**.

The explosive **204** may be adhered to the explosive structures **200***a*-**200***d*, for example, using an adhesive, such as a spray adhesive, tape, two-sided tape, or any suitable adhesive. The explosive **204** also may be coupled to the structure via mechanical devices, such as zip ties, string, paracord, rope, hooks, or other suitable device. The explosive **204** also can be formed integrally with the split tube **100** or the projectile **206**. Certain explosives **204**, such as sheet explosive or others, may be manufactured with an adhesive tape on at least one side of the explosive **204**. In this case, the explosive **204** can be adhered to the explosive structures **200***a*-**200***d* by removing a sacrificial member on the exterior of the adhesive and pressing the explosive **204** to the split tube **100** or the projectile **206**.

The methods to attach the explosive **204** and/or the projectile **206** are suitable with any explosive structure described herein.

FIGS. **3**A and **3**B depict an exemplary explosive structure **300** comprising a split tube **100**, a sheet explosive **204** disposed on an inside of the split tube **100**, and a projectile **206** disposed on an outside of the split tube **100**. FIG. **3**A is a perspective view of the explosive structure **300** in the rolled, undeployed state **100***a*. FIG. **3**B is a perspective view of the explosive structure **300** in the linear, deployed state **100***c*. As shown in FIGS. **3**A and **3**B, the projectile **206** has a slim, flat profile, which, together with the flat profile of the sheet explosive **204**, facilitates the flat shape of the split tube **100** when the explosive structure **300** is in the rolled, undeployed state **100***a*.

As shown in FIG. **3**A, a primer, such as a pigtail **302**, may be attached to the explosive **204** to initiate detonation of the explosive **204** in any of the explosive structures described herein. The pigtail **302** can comprise a length of detonating cord, explosive, or other detonating material coupled to the explosive **204** on one end and to blasting caps (not depicted) on an opposite end. The blasting caps can be initiated by any suitable means, which initiates the detonating material, which initiates the explosive **204** in the explosive structure. An exemplary pigtail **302** is illustrated in FIG. **3**A.

FIG. **3**C is a cross-sectional view of an explosive structure **300'** comprising a split tube **100** profile that envelops the explosive **204** and the projectile **206** on at least three sides to provide an overall flat profile for the explosive structure. The explosive structure **300'** is depicted in FIG. **3**C in the rolled, undeployed state **100***a*. The split tube **100** is provided with a first channel **302** in which the projectile **206** is disposed and a second channel **304** in which the explosive **204** is disposed. In this manner, a thickness of the explosive structure **300'** is controlled to a desired thickness. If the projectile **206** and the explosive **204** do not protrude past the channels **302**, **304**, respectively, then the thickness of the explosive structure **300'** is not more than the thickness of the split tube **100**. If the projectile **206** and/or the explosive **204** extend past the channels **302**, **304**, respectively, then the thickness of the explosive structure **300'** is more than the thickness of the split tube **100**; however, the thickness is less than if the channels **302**, **304** were not provided. The overall flat profile of the explosive structure **300'** further facilitates the flat shape of the split tube **100** when the explosive structure is in the rolled, undeployed state **100***a*.

The projectile **206** and the explosive **204** can be added to the split tube **100** to create the explosive structures **300**, **300'**. Alternatively, the split tube **100** can be manufactured to include the projectile **206**, and the explosive **204** can be added to the split tube **100**/projectile **206** combination to create the explosive structures **300**, **300'**. As shown in FIGS. **3**A-3C, the projectile **206** is a metal band. However, any suitable projectile **206** may be utilized.

In each case, a flatter profile of the explosive structure allows the explosive structure to better maintain the rolled, undeployed state **100***a*. For example, a flatter profile helps a split tube **100** formed from a bistable tape to maintain its stable position in the rolled, undeployed state **100***a* without restraint or with less restraint.

The rolled, undeployed state **100***a* and the linear, deployed state **100***c* apply to the explosive structures described herein. The split tube **100** combined with the explosive **204** and/or the projectile **206** maintains the characteristics of the split tube **100** discussed previously. Bulkier explosives **204** may affect the ability of the split tube **100** to roll into a flat, undeployed state. When bulkier explosives **204** are used in the explosive structures described herein, the split tube **100** may be rolled into a flattened roll as the undeployed state (as shown in FIG. **10**A) or folded into a serpentine pattern as the undeployed state (as shown in FIG. **10**B). These alternative undeployed states are suitable for the innovations described herein.

Multiple explosive structures as described herein may be connected together to create longer explosive structures and/or to create explosive structures having other than a straight configuration. FIGS. **4**-**6** depict connectors for coupling multiple explosive structures together.

FIG. **4** is a perspective view of a straight connector **400** for connecting two explosive structures in an end-to-end configuration. As shown in FIG. **4**, the connector **400** comprises a tubular section **402** corresponding to the curved profile of the deployed split tube **100**. Additionally, the tubular section **402** is sized corresponding to an exterior size and shape of the deployed split tube **100**. The connector **400** further includes a lip **404** on one or both edges of the connector **400**. The connector **400** may be flexible to snap around the ends of two split tube s **100** by pressing the connector **400** over the split tubes **100** (either individually or simultaneously) until the lip(s) **404** of the connector **400** snaps over the longitudinal edges of the split tubes **100**. Alternatively, an end of one split tube **100** is inserted into an end of the connector **400**, and then an end of the other split tube **100** is inserted into the other end of the connector **400**.

The connector **400** also can include one or more knobs **406** on an interior of the connector **400**. The knob **406** protrudes into an interior of the connector **400** and is configured to mate with a corresponding aperture near the end of the split tubes **100** inserted into the connector **400**. A split tube **100** is inserted into an end of the tube connector, the knob **406** is depressed toward an exterior of the connector **400** and hinges outward. Then, the knob **406** springs into the aperture of the inserted split tube **100** when the aperture and the knob **406** are aligned. As shown in FIG. **4**, the knob **406** is attached to the connecter **400** by an elongated section **406***a* in the wall of the split tube **100**. The elongated section **406***a* provides a hinge arm allowing the knob **406** to be pushed outwardly and then spring back when aligned with the aperture in the split tube **100**.

The knob **406** also can facilitate aligning the split tubes **100** in the connector **400** without engaging in an aperture of one or more of the split tubes **100**. For example, the knob **406** can function as a stop to prevent further insertion of the split tubes **100** into the connector **400**. In this manner, each split tube **100** may only be inserted into the connector **400** until an end of the split tube **100** contacts the knob **406**.

FIG. **5** is a perspective view of a hinged, straight connector **500** for connecting two explosive structures in an end-to-end configuration. The connector **500** is similar to the connector **400** with the addition of a hinged door **502**. The hinged door **502** includes alternating tabs **503***a* that mate with alternating tabs **503***b* in the connector **500**. The alternating tabs **503***a*, **503***b* are coupled together via a hinge pin **503***c* extending through the alternating tabs **503***a*, **503***b* to secure the door **502** in a hinged relationship to the connector **500**. Opening the door **502** can allow an easier snap fit or insertion of the split tubes **100** into the connector **500**. Then, the door **502** is closed over the inserted split tubes **100**, and a latch **504** in the door **502** engages grooves **506** on the connector **500** to latch the door **502** in a closed position. Alternatively, an end of one split tube **100** is inserted into an end of the connector **500**, and then an end of the other split tube **100** is inserted into the other end of the connector **500**, after which the door **502** is closed and the latch **504** is engaged.

The connectors can be shaped to form desired configurations of explosive structures. Straight connectors, as described with reference to FIGS. **4** and **5**, create a straight explosive structure. Tube connectors having a 22.5-degree, 45-degree, 60-degree, 90-degree, or other angle can be used to create structures having other orientations. FIG. **6** is a perspective view of an angled connector **600** for connecting two explosive structures in an angled configuration. The angled connector **600** includes tubular sections **602**, **604** with corresponding openings **602***a*, **604***a*. The tubular sections **602**, **604** are connected in a 90-degree angle to create a 90-degree connector. Although depicted as a 90-degree connector in FIG. **6**, the tubular sections **602**, **604** may be coupled together via any desired angle, such as the angles described previously. A first explosive structure is inserted into the opening **602***a* of the angled connector **602**, and a second explosive structure is inserted into the opening **604***a* of the angled connector **604**. In this manner, the two explosive structures are connected in a 90-degree angle, or at any other angle corresponding to the angle of the connector **600**. The angled connector also may incorporate other features discussed with regard to FIGS. **4**A and **4**B, such as the knob **406**, lips **404**, and or the hinged door **502** and latch **504**, **506**.

FIGS. **7**A-**7**B are plan views of various configurations created by connecting multiple explosive structures **700** using connectors **400**, **500**, and/or **600**. FIG. **7**A is a plan view of a rectangular configuration **700** comprising multiple explosive structures **700** connected by multiple straight connectors **400** and multiple angled connectors **600** (90-degree connectors). FIG. **7**B illustrates a plan view of a triangular configuration **710** comprising multiple explosive structures **700** connected by multiple straight connectors **400** and multiple angled connectors **600**, **712** (a 90-degree connector and two 45-degree connectors). The explosive structures **700** may be any of the explosive structures described herein.

When multiple explosive structures are connected, the explosives **204** of each connected structure are coupled together via a length of shock tube, detonation cord, or other suitable material, such that detonation of the explosive **204** of one explosive structure will trigger detonation of the explosive **204** of the next explosive structure coupled thereto.

A nose cone can be provided and shaped to slip over the end of a deployed split tube **100** to provide a blunted end of the split tube **100** and the explosive structure. In this manner, a deployed explosive structure with a nose cone can be pushed forward into an object to be breached, or into a hole in the ground, wall, door, or other structure. The nose cone prevents snagging of the end of the explosive structure and facilitates insertion of the explosive structure.

FIGS. **8**A and **8**B depict an exemplary nose cone **800**. FIG. **8**A is a perspective view of the nose cone **800** for an explosive structure. FIG. **8**B is a cross-sectional view of the nose cone **800** for an explosive structure. As shown in FIGS. **8**A and **8**B, the nose cone **800** includes a conical section **802** connected to a cylindrical section **804**. Walls **804***a*, **804***b* of the cylindrical section **804** form a groove **806** around a perimeter of an open end of the nose cone **800**. The groove **806** corresponds to the shape of the split tube **100** of the explosive structure and is sized to accommodate a thickness of the walls of the split tube **100**. The groove **806** can be sized to hold the nose cone **800** and split tube **100** together via compression fit. As shown in FIGS. **8**A and **8**B, the nose cone **806** comprises holes **804***c* in the sides, which can receive a projectile fastener to hold the projectile **206** in a desired position. Tabs, hooks, or other protrusions **808** on an interior of the nose cone **800** also can be included to attach a projectile fastener. Additionally, the nose cone can include a hook **820** at an apex of the conical section **802** of the nose cone **800**. A projectile **206** having an end attached to the hook **820** will be retained in a center of the nose cone **800**, thereby suspending the projectile **206** in a longitudinal center of a split tube **100** of an explosive structure connected to the nose cone **800**.

A nose cone **800** may be utilized on one or both ends of a split tube **100** of an explosive structure. Additionally, the conical section **802** of the nose cone **800** may be blunted to any desired degree by reducing the length of the conical section **802**. The conical section **802** may be reduced in length or reduced to a spherical section. The conical section **802** also may be replaced with a linear section more in the form of an end cap than a nose cone.

If an end piece, such as a nose cone **800**, end cap, or tube connector **400**, **500**, **600**, is utilized, the projectile connectors of the projectile **206** may be attached to the end piece on one end of the split tube **100** and/or the end piece on the other end of the split tube **100**. The end pieces are configured with a hole, indent, design, tab, hook, or other suitable connector recess to accept the tube connectors. Twisting the end piece around the ends of the split tube **100** of the explosive structure moves the connector recess around the split tube **100** to control a height of the projectile **206** above the explosive **204**. The projectile connectors may be connected to the end pieces via any suitable manner. For example, the end pieces may include a cross-member on an interior diameter or other protrusion inside or outside the end pieces, and the projectile connector may be attached to these items.

Although described previously as using a fastener cord between the projectile connector and the projectile **206**, the fastener cord may be omitted or supplied in the end piece. For example, the hooks or other projectile connectors may be connected directly to the projectile **206** and/or the end piece or connectors in the end piece.

Connecting the projectile **206** to the nose cone, end cap, tube connector, and/or other end piece can increase the explosive structure's integrity to hold the various components in place. For example, a projectile **206** connected to a nose cone on one end of a split tube **100** and an end cap on another end of the split tube **100** will hold the nose cap and the end cap on the ends of the split tube **100**.

The end caps and connectors described herein may retain an inserted split tube via compression fit.

FIG. **9** is a cross-sectional view of an explosive structure **900** comprising a suspended projectile **206**. As shown in FIG. **9**, the explosive structure **900** comprises an explosive **204** disposed on an interior of a split tube **100**. A nose cone **800** is provided on one end of the split tube **100**, and an end cap **902** is provided an opposite end of the split tube **100**. An explosive **204** is suspended between the nose cone **800** and the end cap **902** via hooks **820** and **920** in the nose cone **800** and the end cap **902**, respectively. Connecting cords or devices **906** can be utilized to connect the projectile **206** to the hooks **820**, **920**. The projectile **206** is suspended within the tubular structure of the split tube **100**. Any suitable projectile **206** may be utilized as the suspended projectile **206**. One example of a suspended projectile **206** is a chain having a desired length.

Suspending the projectile **206** above the explosive **204** provides different dynamics to the explosive effect compared to placing the projectile **206** in contact with, or closer to, the explosive **204**. For example, more explosive **204** may be used in the suspended configuration without the explosion degrading the projectile **206** too significantly. The increased explosive **204** propels the projectile **206** and/or the projectile **206** fragments with increased force, which increases the effect on target. Using more explosive **204** when the projectile **206** is positioned in contact with the explosion can increase fragmentation of the projectile **206**, which can decrease the effect on the target. The amount of explosive **204**, the position/configuration of the projectile **206**, and the type of projectile **206** can be selected to provide a desired effect on target.

An exemplary pigtail **302**, as described herein, is illustrated in FIG. **9** coupled to the explosive **204**.

In operation, detonation of the explosive **204** on the split tube **100** propels the projectile **206** away from the explosive **204**. In this manner, the direction of the projectile **206** and projectile **206** fragments can be controlled in a desired direction, such as toward a desired obstacle or object.

For example, an explosive structure can be pushed under or into an obstacle, such as concertina wire or barbed wire, with the projectile **206** facing the obstacle. Detonation of the explosive **204** propels the projectile **206** and/or projectile **206** fragments into the obstacle, thereby destroying or moving at least a portion of the obstacle to allow passage.

The projectile **206** can comprise any suitable material and can be tailored to operate with a desired type and amount of explosive **204**. As depicted in FIG. **2**, the projectile **206** can comprise a metallic band that is continuous along its length and having a desired width across the transverse direction of the split tube **100**. A single projectile **206** or multiple projectiles **206** can be used to produce the desired effect.

Other suitable projectile materials include chain, metal pipe or tubing, steel shrapnel, wire cable, sprung metal, wire mesh, wire weave, weaved metal cable, sheet metal, metal rods, high-density non-metallic materials, rock, sand, or any other suitable material that provides a desired effect when propelled by the explosive **204** and/or when fragmented and propelled by the explosive **204**.

The projectile **206** can be fragmentable in conjunction with a type and/or amount of explosive **204**. A fragmentable projectile **206** produces shrapnel directed at the target. The projectile **206** can be chosen to remain substantially intact or to produce large fragments in conjunction with a type and/or amount of explosive **204**. For example, a long projectile **206**, such as chain, that remains substantially intact may cut through an obstacle, such as concertina wire or barbed wire. This type of projectile **206** also may grab the obstacle, such as concertina wire or barbed wire, and move the obstacle from its position.

The projectile **206** may be chosen to be fragmentable, partially fragmentable, or not fragmentable. For example, when clearing concertina wire, it may be desirable for the projectile **206** to remain intact or to only fragment into longer sections. Such longer sections may be twelve inches or longer, although the desired length may be longer or shorter depending on the target and the desired effect. In this manner, the explosive **204** propels the projectile **206** (in whole or in sections) toward the object, the lengths of projectile **206** "grab" the object, and the momentum of the projectile **206** carries the object away from the object's initial location. Alternatively or additionally, the longer sections of projectile **206** may tear through an object as it passes therethrough.

One particular projectile **206** is sprung metal. The sprung metal's natural shape is a rolled, tubular configuration having a length in a longitudinal direction. The sprung metal can be compressed into a rolled, small cylindrical shape and held in position with a pin. Removal of the pin allows the spung metal to return to the rolled, tubular configuration. The rolled, tubular configuration is useful as a projectile **206** with the explosive structures described herein. The sprung metal may be transported easily in the compressed, cylindrical shape and then deployed when preparing an explosive structure, for example, when near the target.

The projectile **206** may attached to the explosive structure via any suitable manner. For example, the projectile **206** may be taped, glued, or otherwise attached to the split tube **100** or to the explosive **204** that is attached to the split tube **100**. Alternatively, the projectile **206** may be laid on the split tube **100** or the explosive **204** as desired. As described previously, the projectile **206** may be positioned relative to the explosive **204** such that the projectile **206** does not touch the split tube **100** or the explosive **204** along its entire length. Additionally, the configuration of an explosive structure can position the projectile **206** between the split tube **100** and the explosive **204**. In this configuration, the explosive **204** will propel the projectile **206** through the split tube **100** toward the target.

The explosive structure described herein is useful to clear infantry-type obstacles, such as concertina wire and mine fields, using the operation described previously. The explosive structure described herein also has many other uses. For example, the structure can be placed on the ground facing up or facing in a desired direction and used as an anti-personnel mine, similarly to a "claymore" mine. For an anti-personnel mine, a ball shot type of projectile **206** may be poured into the open side of the split tube **100** and held in place by the curvature of the split tube **100**. Sand or rock also are useful projectiles for the anti-personnel mine configuration. The structure can be detonated manually or via a trip mechanism. In other uses, the structure can be placed vertically to breach/clear a door, wall, vegetation, or other object. The explosive structure can be placed under, in, on, or over an object to be breached/destroyed, such as a door, wall, concertina wire, mine field, or other structure.

The amount and type of explosive **204** can be chosen to provide the desired effect when combined with the selected projectile **206**. More explosive **204** may produce more fragmentation and/or projectile **206** speed. Less explosive **204** may produce lesser fragmentation while still generating enough projectile **206** speed to provide the desired effect on the target.

The explosive **204** can be any suitable type of explosive **204**, and generally an explosive that is flexible to accommodate the rolling and unrolling of the explosive structure. For example, the explosive **204** can be sheet explosive; detonation cord; malleable explosives such as RDX, C4, plastique, gel, or other malleable explosive, or any suitable explosive.

The explosive structures and methods to deploy explosive structures described herein can provide many advantages. The split tube **100** described herein is rigid in the linear, deployed state **100***c*. Accordingly, the deployed explosive structure is a rigid structure that can promote faster and more accurate placement of the explosives **204**/projectiles **206**, can hold the explosives **204**/projectiles **206** in a desired position, and can facilitate reaching the explosives **204**/projectiles **206** away from the operator. Additionally, deploying the explosive structure is an easier task as the split tube **100** can be fed out from the rolled state directly into the linear state.

Furthermore, the split tube **100** can be self-deploying. Once a portion of a bistable split tube **100** is moved from the rolled, undeployed position, the remainder of the split tube **100** will unroll to extend the split tube **100** to the linear, deployed position. Such deployment can be almost instantaneous, reducing the time to deploy the explosive structure and reducing the time on target (or otherwise in the dangerous situation).

The explosive structures and methods described herein provide a structure that can be assembled in a rigid state (the linear, deployed state **100***c* of the tape), transitioned to a reduced size for storage or transportation (the rolled, undeployed state **100***a* of the tape), and then transitioned again to the rigid state (the linear, deployed state **100***c* of the tape) for deployment of the explosive **204** and projectile **206**. The split tube **100** described herein can allow easier assembly of the explosive structure in the rigid state, faster and easier rolling of the explosive structure for storage and transportation, and faster and easier deployment of the explosive structure to the rigid state for deployment in the field.

The explosive structures and methods described herein also can reduce or eliminate damage to the explosive **204** and projectile **206** when moving the explosive structure from the rigid state, to the stored state, and back to the rigid state. The design of the split tube **100** reduces force applied to the attached explosive **204** during transitions as the split tube **100** absorbs certain transverse forces by transitioning from a curved profile when deployed (linear) to a flat profile when undeployed (rolled), and when transitioning from the flat profile when undeployed (rolled) to the curved profile when deployed (linear).

In another example, the explosive structures described herein may comprise a foldable support structure in place of the split tube. The foldable support structure can comprise multiple foldable sections connected by hinges, whereby the foldable sections can fold inwardly via the hinges to reduce the size of the support structure and unfold outwardly via the hinges to create a desired length of support structure. The foldable sections can lock in the unfolded position to create a sturdy support structure across the length of the unfolded support structure. For example, hinges connecting the foldable sections can lock in the unfolded position to lock the foldable sections in the unfolded position. Alternatively, or additionally, the foldable sections can have overlapping ends that overlap and engage in the unfolded position to hold the unfolded structure in position. In another example, sections of split tube **100** can be used as the hinges attaching the foldable sections. The split tube hinges will self-deploy to the linear position to unfold the foldable sections and to hold the foldable sections in a linear state. As the split tube **100** is rigid in the deployed state, the split tube hinges provide a rigid connection for the unfolded sections. The foldable support structure may be formed from any suitable materials, such as, for example, plastic, wood, fiberglass, composites, or any other suitable material.

The components and systems described herein can be formed of any suitable material. A person having ordinary skill in the art and the benefit of this disclosure will understand that multiple options exist for manufacturing the components and structures described herein.

The example systems, methods, and components described in the embodiments presented previously are illustrative, and, in alternative embodiments, certain components can be combined in a different order, omitted entirely, and/or combined between different example embodiments, and/or certain additional components can be added, without departing from the scope and spirit of various embodiments. Accordingly, such alternative embodiments are included in the scope of the following claims, which are to be accorded the broadest interpretation so as to encompass such alternate embodiments.

Although specific embodiments have been described above in detail, the description is merely for purposes of illustration. It should be appreciated, therefore, that many aspects described above are not intended as required or essential elements unless explicitly stated otherwise. Modifications of, and equivalent components or acts corresponding to, the disclosed aspects of the example embodiments, in addition to those described above, can be made by a person of ordinary skill in the art, having the benefit of this disclosure, without departing from the spirit and scope of the invention defined in the following claims, the scope of which is to be accorded the broadest interpretation so as to encompass such modifications and equivalent structures.

What is claimed is:

1. An explosive structure, comprising:

a split tube having a length, the split tube being rollable into a roll in an undeployed state and deployable into a straight form along its length in a deployed state;

a nose cone coupled to one end of the split tube;

an explosive coupled to at least a portion of the length of the split tube; and

a projectile disposed relative to the explosive.

2. The explosive structure according to claim **1**, wherein the projectile is disposed relative to the explosive by being disposed adjacent to the explosive.

3. The explosive structure according to claim **1**, wherein projectile is disposed relative to the explosive by being disposed on a side of the split tube that is opposite to the side on which the explosive is coupled.

4. The explosive structure according to claim **1**, wherein the projectile is disposed relative to the explosive by being suspended inside the split tube without contacting the explosive.

5. The explosive structure according to claim **1**, wherein the projectile is fragmentable.

6. The explosive structure according to claim **1**, wherein the projectile comprises chain, metallic band, sprung metal, metal pipe, metal tubing, steel shrapnel, wire cable, wire mesh, wire weave, weaved metal cable, sheet metal, metal rods, high-density non-metallic material, or ball shot.

7. The explosive structure according to claim **1**, the split tube comprising a bistable, self-deployable structural tape, the structural tape having a rolled, flat transverse profile in the undeployed state, and the structural tape having a linear, curved transverse profile in the deployed state, the structural tape being stable in the undeployed state and in the deployed state and being unstable when between states such that transitioning one end of the structural tape from the rolled shape to the linear shape places the tape in an unstable state causing the tape to self-deploy to the deployed state.

8. The explosive structure according to claim **1**, wherein the split tube comprises two sections, the explosive structure further comprising a connector that couples the two sections of split tube together.

9. The explosive structure according to claim **1**, wherein the split tube comprises a bistable structural tape comprising an undeployed state and a deployed state, the structural tape having a rolled, flat transverse profile in the undeployed state, and the structural tape having a linear, curved transverse profile in the deployed state.

10. The explosive structure according to claim **9**, the structural tape further being stable in the undeployed state and in the deployed state and being unstable when between states such that transitioning one end of the tape from the rolled shape to the linear shape places the tape in an unstable state causing the tape to self-deploy to the deployed state.

11. The explosive structure according to claim **1**, wherein the split tube is a metallic tape.

12. The explosive structure according to claim **1**, wherein the explosive structure can be compacted into the undeployed state of the split tube and extended into the deployed state of the split tube.

13. The explosive structure according to claim **1**, further comprising an adhesive that couples the explosive to the split tube.

14. The explosive structure according to claim **13**, wherein the adhesive is an adhesive tape, a two-sided adhesive tape, or a spray adhesive.

15. The explosive structure according to claim **1**, further comprising an adhesive member coupled to the explosive structure to connect the explosive structure to another structure.

16. The explosive structure according to claim **1**, wherein the explosive comprises a cord explosive.

17. The explosive structure according to claim **1**, wherein the explosive comprises a sheet explosive.

18. The explosive structure according to claim **1**, wherein the explosive is disposed on a convex side of the split tube when the split tube is in the deployed state.

19. The explosive structure according to claim **1**, wherein the explosive is disposed on a concave side of the split tube when the split tube is in the deployed state.

20. The explosive structure according to claim **1**, wherein a rolled profile of the split tube in the undeployed state comprises a flattened roll configuration.

21. A method to support an explosive and a projectile along a linear structure for transportation and deployment, comprising:

providing a bistable, self-deployable structural tape in an undeployed state, the structural tape comprising the undeployed state and a deployed state, the structural tape having a rolled, flat transverse profile in the undeployed state, and the structural tape having a linear, curved transverse profile in the deployed state, the structural tape being stable in the undeployed state and in the deployed state and being unstable when between states such that transitioning one end of the tape from the rolled shape to the linear shape places the tape in an unstable state causing the tape to self-deploy to the deployed state;

deploying the structural tape into the deployed state;

disposing an explosive lengthwise along the deployed structural tape;

coupling a nose cone to one end of the structural tape; and

disposing a projectile lengthwise along the deployed structural tape and relative to the explosive.

22. The method according to claim **21**, further comprising rolling the structural tape, the explosive, and the projectile into the undeployed state of the structural tape.

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